RESEARCH AND TECHNOLOGIC WORK ON COAL AND RELATED INVESTIGATIONS, 1954

BY E. P. CARMAN AND D. L. CALDWELL

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E. P. Carman[1] and D. L. Caldwell[2]

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INTRODUCTION AND SUMMARY

This report is the 19th in a series summarizing Bureau of Mines research and technologic work on coal and related investigations. The first 17 reports covered fiscal years; however, the 18th report[3] covered the 18 months from July 1, 1952, to December 31, 1953, to permit the publication of this and subsequent reports on a calendar-year basis. Most of the material in this report relates to publications by Bureau authors issued during the reporting period. Some work is referred to on which the results have not yet been published or may not be published for security or other reasons. In a few instances publications are mentioned that were issued before the reporting period but were not included in previous reports. Further details on the published work described herein may be found in the publications cited in the footnotes.

Research and technologic work on coal by the Bureau is directed toward developing and encouraging increased conservation of coal resources through safer and more efficient mining, preparation, and utilization. Significant advances were made during the year in these fields, particularly in coal-mine safety and in preparation and utilization of the various ranks of coals.

A 5-year bibliography of Bureau publications relating to coal[4] supplemented previous bibliographies by extending the period covered to January 1, 1950. A two-part report on the technology of lignitic coals was issued during 1954.[5] [6] This comprehensive summary includes information on present commercial practice in the United States and Europe and data on research by the Bureau of Mines and other investigators.

Under the Federal Government program of technical assistance to foreign underdeveloped areas, Bureau of Mines technologists, under the auspices of the Foreign Operations Administration (now International Cooperation Administration, U. S. Department of State), provided field technical assistance on coal problems to five foreign countries, Afghanistan, Colombia, India, Pakistan, and the Philippine Islands. Foreign technologists have been trained by Bureau personnel in the United

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[3] Brown, R. L., and Carman, E. P., Report of Research and Technologic Work on Coal and Related Investigations, July 1, 1952, to December 31, 1953: Bureau of Mines Inf. Circ. 7699, 1954, 102 pp.

[4] Carman, E. P., Opperman, M., Nishiyama, S., and Racoosin, L., Bibliography of Bureau of Mines Investigations of Coal and its Products, 1945 to 1950: Bureau of Mines Bull. 528, 1954, 60 pp.

[5] Bureau of Mines, Technology of Lignitic Coals, Part I: Inf. Circ. 7691, 1954, 142 pp.

[6] Bureau of Mines, Technology of Lignitic Coals, Part II: Inf. Circ. 7692, 1954, 120 pp.

States and abroad. These activities were conducted at the request of the various countries and the United States Foreign Operations Administration.

Coal sampling and analysis and fuel-burning consulting services for various Government agencies were continued. These activities provided coal-analysis data that serve as the basis for the entire Government coal-purchasing program and for the economical utilization of fuel, resulting in substantial savings to the Federal Government. The Bureau is making a critical examination of coal-analysis methods to evaluate and improve methods and techniques by increasing the accuracy or decreasing the amount of time required to analyze coal, coke, and coal-mine dust samples. An improved low-temperature carbonization-assay method particularly suited to use with low-rank coals has been devised for determining the yields of carbonization products.

The Bureau has continued its cooperation with the Classification Working Party of the Coal Committee, Economic Commission for Europe, in formulating systems of coal classification. A classification system has been accepted for coals higher in rank than lignite and brown coal. Methods of classifying the lower rank coals are being investigated.

Coal constitution and petrographic studies have included investigation of the occurrence and nature of rare and uncommon elements in coal, comparison of infrared spectra of different carbonaceous materials, study of molecular structure of coal, and petrographic examination of North Dakota lignite by a new thin-section method.

Five county reports on the recoverable reserves of coking coal in the Appalachian coal fields, published during the year, covered counties in Kentucky, Tennessee, and West Virginia. At the end of the fiscal year, June 30, 1955, the reserve phase of the coking-coal studies was transferred to the Federal Geological Survey, whereas the Bureau of Mines will continue reporting by counties the results of its studies of preparation and carbonizing characteristics of these coals. Preparation studies of coals from 1 county in Tennessee and 2 in West Virginia were published during the year. Reports were issued on the carbonizing characteristics of coals from one county each in Pennsylvania and Tennessee.

In Alaska drilling and other exploratory investigations are outlining additional coal reserves in the Matanuska Valley to assure an adequate fuel supply for civilian and military use in the Anchorage area.

The Bureau of Mines has been interested in developing safer and more efficient mining methods that will increase recovery of coal, thereby conserving resources through more efficient development and use. The coal planer, applied on a modified longwall face in bituminous coal, achieved these objectives. Planers were used successfully at three bituminous mines during the year, and another had been purchased for installation. Preliminary experiments were conducted by the Bureau with its vibrating-blade coal planer in Pennsylvania anthracite, and although some difficulties were encountered, it was found that coal planers can be used in coal as hard as anthracite.

Possible application of continuous-type mining machines to longwall mining of bituminous coal was studied also. Methods of roof support in anthracite and bituminous-coal mines using roof bolts, collapsible steel props, and backfilling (in the anthracite region) to permit controlled subsidence indicated the feasibility of such applications for the mining of coal pillars hitherto regarded as unrecoverable. Data obtained in a Bureau of Mines study of the use of continuous mining machines in bituminous-coal mining showed greater productivity of such machines compared with other types of mechanical mining employed at the same mines.

Since fine-coal cleaning is becoming a problem of increasing importance to the coal industry, special attention by the Bureau of Mines was devoted to cleaning and dewatering fine coals. Kerosine froth flotation of fine coal, as developed by the Bureau, has been adopted commercially, and Bureau studies have been directed toward improving capacity of this type equipment and determining its suitability for sulfur removal from coking coals. The feldspar jig, widely used in Europe for fine-coal cleaning, was studied to determine capacity factors and applicability to American coal-cleaning problems. Pilot-plant studies also were made comparing the use of pulverized refuse and magnetite in the cleaning of coal by heavy-medium separation and to determine the suitability of the heavy-medium process for recovering coal from bituminous-coal-mine-refuse piles. More efficient methods of crushing, cleaning, and dewatering anthracite fines were investigated.

Better utilization of fuel, in effect, extends and conserves our reserves of these fuels. In furthering the Bureau of Mines conservation policies, a report was published giving data on crossfeed ignition and burning to supplement earlier published data on underfeed and overfeed combustion. Performance tests were made on an incinerator developed by the Bureau of Mines for use in hospitals, universities, and small commercial projects for disposal of radioactive wastes. Tests were made on the performance of portable Army heating equipment with various liquid fuels. Advice and assistance were furnished by the Bureau of Mines to Federal agencies on fuel-burning and boiler-water problems, resulting in substantial savings to the Government through increased efficiency of operation and reduced maintenance costs. Additives were studied for their effectiveness in reducing sludge formation during the storage of No. 6 fuel oil and for controlling the formation of soot deposits. In a cooperative investigation, coal-washery refuse was successfully burned to produce a lightweight concrete aggregate by a method in which data developed in the Bureau's combustion studies were applied. Publications and consulting services on smoke abatement and related problems were furnished to Federal and municipal agencies requesting them. New England industrial plants were inspected to determine possibilities of alleviating sources of stream pollution and, where economically feasible, to recover valuable products heretofore lost.

Coal-carbonization studies included determination of carbonizing properties, yields of gas and chemical products, and swelling properties of American coals and effects of operating variables on coke yields and properties. Colombian and Philippine coals were tested for their suitability as metallurgical fuel for use in those respective countries. Specially prepared coal-tar pitches were carbonized under closely defined conditions to obtain data on the mechanism and kinetics of coal carbonization. Other studies included investigation of the effect of blending on the carbonization of various carbonaceous materials and the effect of pretreatment of coal on its carbonizing properties. Blends of selected anthracite fines with suitable coking coals appear to have certain advantages over other fuels in some commercial metallurgical processes.

Bureau of Mines laboratory facilities were enlarged by completion and occupation of the Appalachian Experiment Station at Morgantown, W. Va., shown in figure 1. Bureau investigations of the conversion of coal to gas and the use of tars obtained by low-temperature carbonizing of coal will be carried on in the new laboratories and pilot plant. Tests were made at this station on the gasification of pulverized anthracite with oxygen and steam.

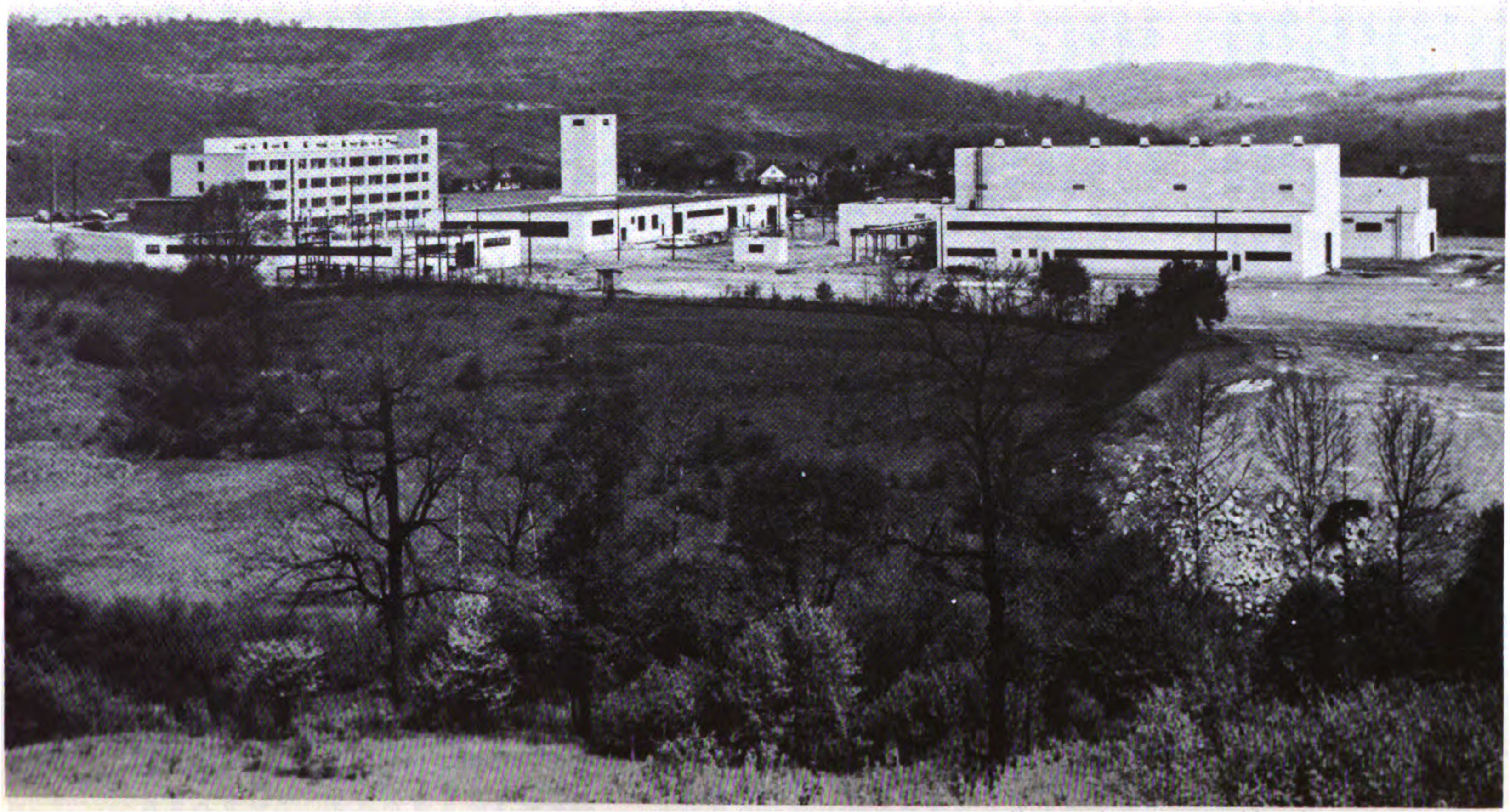

Figure 1. - Appalachian Experiment Station, Federal Bureau of Mines, Morgantown, W. Va.

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Pilot-plant development of entrained gasification of coal with oxygen at atmospheric pressure was stopped by the Bureau when an industrial gasifier was erected that incorporated many features that had been developed at the Morgantown, W. Va., station. A method was developed for removing carbon dioxide from synthesis gas, and work continued on the removal of dust from such gas.

In the reactivated project on underground coal gasification at Gorgas, Ala., a test of hydraulic fracturing of the coal bed before ignition showed that permeability of the bed to gases was greatly increased over a substantial area by such fracturing. This method, now used for increasing the productivity of oil wells, appears to be an alternative method to electrolinking for opening underground passages in coal beds for gasification with a minimum of mining.

Two methods for carrying out the gas-synthesis process are currently being studied by the Bureau of Mines. One of these was investigated as a means for producing chemicals. The first part of a comprehensive bibliography of this process was published.[7] Related studies of the oxo synthesis were concerned mainly with the properties of the catalyst.

In the hydrogenation of coal, methods of analysis and separation of products were investigated. Difficulties experienced in controlling the hydrogenation of coal at high temperatures in a single-step process for direct conversion of coal to liquid products necessitated redesigning the pilot plant. Details of progress in gasification, gas synthesis, and coal hydrogenation during 1953 are published in the Annual Report of the Secretary of the Interior for 1953 on synthetic liquid fuels.[8]

ACKNOWLEDGMENTS

This report covers work done under the technical direction of many members of the staff of the Bureau of Mines, who cooperated and assisted in preparing data and material for use in this report.

The following organizations, institutions, and companies have cooperated with the Bureau by helping to finance research projects or arranging for or assisting in conducting research and technologic work on coal. Their cooperation is hereby acknowledged.

Air Reduction Co.
Alabama Power Co.
American Eagle Colliery
Amherst Coal Co.
Amos, A. R. Co.
Army Chemical Corps
Atomic Energy Commission

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[7] Anderson, H. C., Wiley, J. L., and Newell, A., Bibliography of the Fischer-Tropsch Synthesis and Related Processes (in Two Parts). I. Review and Compilation of the Literature on the Production of Synthetic Liquid Fuels and Chemicals by the Hydrogenation of Carbon Monoxide: Bureau of Mines Bull. 544, 1954, 532 pp.

[8] Bureau of Mines, Annual Report of the Secretary of the Interior for 1953, Part I, Oil From Coal: Rept. of Investigations 5043, 1954, 66 pp.; Annual Report of the Secretary of the Interior for 1953, Part II, Oil From Coal: Rept. of Investigations 5044, 1954, 55 pp.

Baukol-Noonan, Inc.
Bell and Zoller Coal Co.
Berwind-White Coal Mining Co.
Bethlehem Mines Corp.
Boeing Airplane Co.
Buckeye Coal Co.
Cebu Portland Cement Co., Manila, P. I.
Central Power Electric Cooperative, Inc.
Chicago, Wilmington & Franklin Coal Co.
Christopher Coal Co.
Colorado Fuel & Iron Co.
Columbia-Geneva Steel Division, United States Steel Corp.
Corporacion Carbonera Colombiana, Cali, Colombia
Corps of Engineers, United States Army
Crucible Steel Co.
Dakota Briquets and Tar Products, Inc.
Damodar Valley Corp., Bermo, India
Department of Public Works, Bureau of Sewers, City of Baltimore, Md.
Division of Geology, State of Tennessee
Dominion Steel and Coal Co., Ltd.
Duquesne Light Co.
Eastern Gas & Fuel Associates
Ebensburg Coal Co.
Eddy Stoker Corp.
Federal Geological Survey
Ford Motor Co.
General American Transportation Co.
Glen Alden Coal Co.
Halliburton Oil Well Cementing Co.
Hazleton Brick Co.
Hudson Coal Co.
Instituto de Fomento Industrial, Bogota, Colombia
International Nickel Co.
Island Creek Coal Co.
Kemmerer Coal Co.
Lehigh Navigation Coal Co.
Lehigh Valley Coal Co.
Lorain Coal & Dock Co.
Mather Collieries
Missouri Basin Field Committee
Northwestern Improvement Co.
Office of the Quartermaster General, Department of the Army
Old Ben Coal Corp.
Pakistan Industrial Development Corp., Karachi, Pakistan
Pennsylvania Coal & Coke Corp.
Pennsylvania Crusher Co.
Philippine Bureau of Mines, Manila, P. I.
Philadelphia and Reading Coal and Iron Co.
Pine Township Coal Co.
Rochester and Pittsburgh Coal Co.
Russell Fork Coal Co.
Standard Oil Development Co.
Tennessee Valley Authority
Tioga Coal Corp.
Truax-Traer Coal Co.

Union Carbide & Carbon Co.
United States Foreign Operations Administration
University of Alabama
University of Maryland
University of Washington
Valley Camp Coal Co.
Wellman Engineering Co.
West Virginia University
Wilmot Engineering Co.

ORIGIN, COMPOSITION, AND PROPERTIES OF COAL AND RELATED MATERIALS

Inspection, Sampling, and Analysis

During the calendar year 1954 coal production exceeded demand, and Federal agencies had no difficulty in obtaining bids to cover their requirements. All agencies except the United States Post Office Department purchased on a guaranteed-analysis basis, including penalties for delivery of substandard coal. The United States Department of the Navy, purchasing coal for the Armed Services, was the largest Federal coal-purchasing agent. Some other departments requiring substantial amounts purchased their own coal, and the General Services Administration purchased for certain Government agencies whose requirements were small. Contracting for coal for the fiscal year 1955 began in February and continued through June.

Coal requirmments of Federal agencies, except the Atomic Energy Commission, Tennessee Valley Authority, and coal purchased for export, were estimated at about 4,500,000 tons for the fiscal year. An increase was noted in requests from Federal agencies for analyses to evaluate coal bids, since more bids were received. Strict adherence to specification requirements was continued regarding consideration of only those mines on which there were Bureau of Mines analysis records. In addition, recommendations were made to some agencies for awarding their contracts.

Reports were made on proximate or ultimate and sulfur- and calorific-value analyses of 9,669 coal samples; on ash-fusing temperature of 3,101 samples; on free-swelling index of 487 samples; and on Hardgrove grindability of 300 samples taken from coal purchased by the Government and from samples taken during tipple and breaker inspections in connection with Federal coal purchases. A total of 1,095 tipple, 59 preparation, and 34 carbonization samples was collected at 303 mines in 6 States; 88,926 gross tons of coal being shipped overseas by the FOA were sampled at Norfolk, Baltimore, and Philadelphia. At the request of the Marine Corps, coal-sampling procedures were reviewed at Camp Lejeune and the Air Station, Cherry Point, N. C., and recommendations were made to correct sampling deficiencies.

Another in the series of annual coal-analyses publications was issued, this one covering tipple and delivered samples of coal collected during the fiscal year 1953.[9]

In Alaska military personnel was trained and certified by the Bureau of Mines as coal samplers at the various military bases. This is a continuing function of the Bureau in Alaska because of the rotation of military personnel. Tipple and special samples from all producing mines were taken and analyzed, and technical advice and assistance were given on coal-bidding procedure, specifications, delivery schedules, storage, and handling problems. The laboratory equipment set up in the space made available on a part-time basis in the Department of Mines building at Anchorage was standardized by a system of crosschecking Alaska samples with the Pittsburgh coal-analysis laboratory. Efforts were continued to find space in which a full-time laboratory could be established.

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[9] Aresco, S. J., Haller, C. P., and Abernethy, R. F., Analyses of Tipple and Delivered Samples of Coal (Collected During the Fiscal Year 1953): Bureau of Mines Rept. of Investigations 5085, 1955, 82 pp.

During the year the coal-analysis laboratory at Pittsburgh, Pa., analyzed 27,099 samples of coal, coke, char, tar, residue, coal-mine dust, and related material. Government purchases of coal on a penalty basis and inspections of tipples provided 9,048 samples, 68 percent of the Government purchase samples came from branches of the Department of Defense. The Bureau of Mines and other Government organizations submitted 4,963 samples in connection with research and exploration projects on coal; and the Coal-Mine Inspection Branch of Accident-Prevention and Health Division sent in 13,088 samples from 3,537 inspections made of coal mines in 19 States, carried out under the provisions of Public Law 552 for determining safety conditions in coal mines. The samples analyzed required 294,593 chemical and physical tests to furnish the information requested.

A question as to whether certain coal samples had deteriorated and suffered a loss in calorific value while stored in sampling cans was responsible for initiating a study to determine the possible extent of such a loss. A study of 6 freshly mined samples of various rank coals from 5 States is still in progress, but preliminary results indicate a possible loss in calorific value of 100 B.t.u. or more after 2 weeks of sealed storage of laboratory samples. The loss was found to depend on the rank of the coal and the length of storage time. Publication of the results is planned upon completion of the study.

Reports of coal analyses showing chemical composition and classification by rank were prepared for 4 publications giving estimates of known recoverable reserves of coking coal in 2 counties in Kentucky, 2 in West Virginia, and 1 in Tennessee.10/ Detailed training in coal analysis was given four FOA trainees from Colombia, Mexico, Formosa, and the Philippine Islands.

10/ Williams, L., Lowe, R., Turnbull, L. A., Carman, E. P., Crentz, W. L., Reynolds, D. A., and Abernethy, R. F., Estimate of Known Recoverable Reserves and the Preparation and Carbonizing Properties of Coking Coal in Putnam County, Tenn.: Bureau of Mines Rept. of Investigations 5029, 1954, 21 pp.
Wallace, J. J., Dowd, J. J., Travis, R. G., Abernethy, R. F., and Reynolds, D. A. Estimate of Known Recoverable Reserves of Coking Coal in Harlan County, Ky.: Bureau of Mines Rept. of Investigations 5037, 1954, 26 pp.
Wallace, J. J., Dowd, J. J., Tavenner, W. H., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Mingo County, W. Va.: Bureau of Mines Rept. of Investigations 5068, 1954, 57 pp.
Wallace, J. J., Dowd, J. J., Tavenner, W. H., Provost, J. M., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Mercer County, W. Va.: Bureau of Mines Rept. of Investigations 5077, 1954, 20 pp.
Wallace, J. J., Dowd, J. J., Travis, R. G., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Perry County, Ky.: Bureau of Mines Rept. of Investigations 5083, 1954, 26 pp.

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Examination of Coal-Analysis Methods

A critical study of methods employed in analyzing coal, coke, and coal-mine dust samples is being made by the Bureau of Mines to determine whether recent developments in laboratory instrumentation and analytical procedures can be utilized either to increase accuracy or to reduce time and operating costs. An investigation was made to determine the possibility of analyzing coal-mine-dust samples for carbon dioxide content by employing a potentiometric titration procedure. The method was not found to be applicable to all samples owing to the natural alkalinity of some coals and variations in composition of the rock dusts, but in many instances a titrimetric procedure can be used advantageously and with reasonable accuracy.

A method of evaluating coal-mine dust samples by physical tests to estimate the total incombustible content was investigated. By combining a color comparison test for light samples and a rapid modified volumeter test for dark samples, it was found possible to evaluate all samples as to their approximate total incombustible content and so to eliminate the time-consuming chemical analysis for approximately 75 percent of the samples received from the coal-mine inspectors. A report is being prepared describing the procedures and giving the limits of combustible content for which the method is applicable.

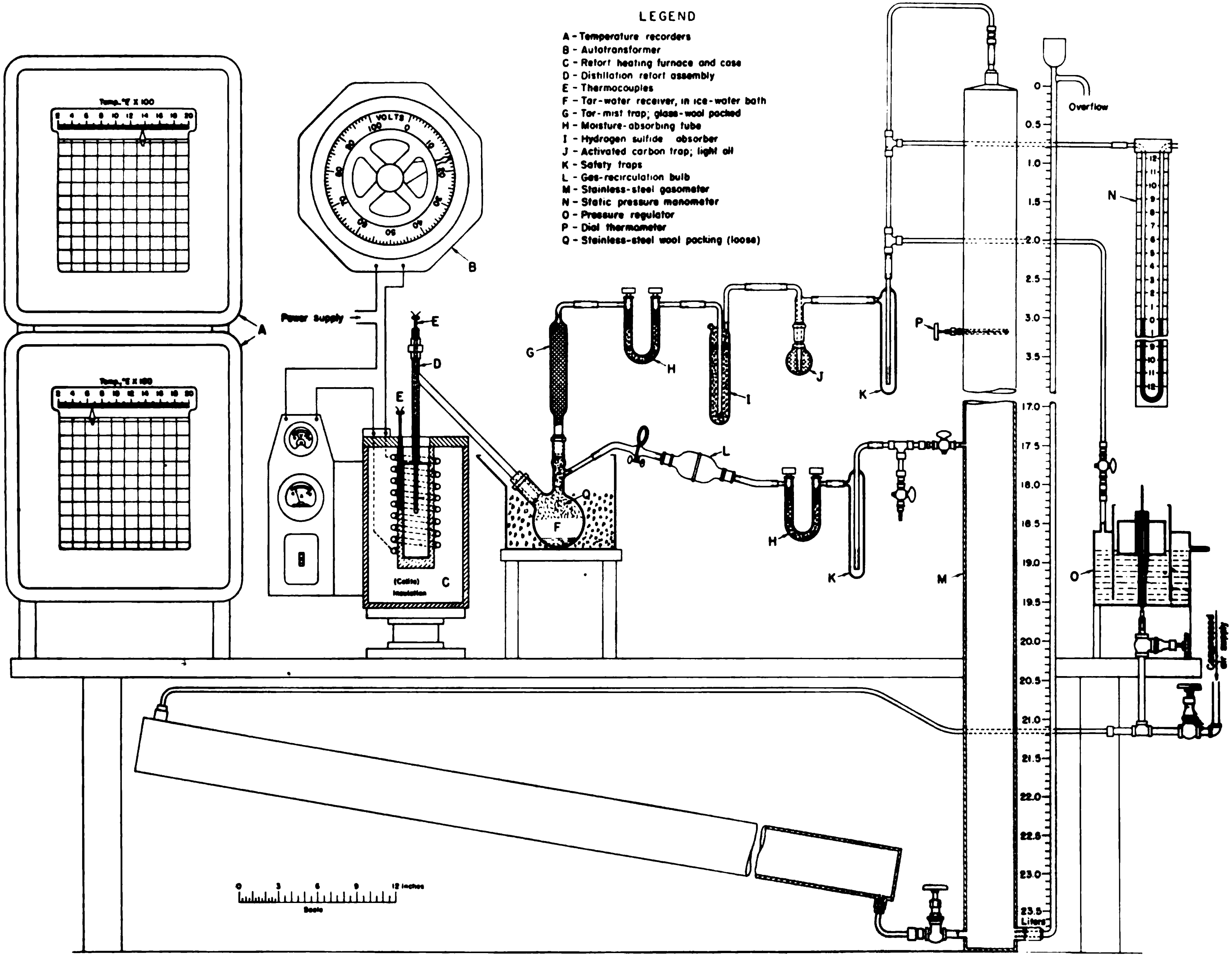
An equilibration method for determining the moisture-holding capacity of coal at 97 percent relative humidity and 30° C. is under consideration as a standard test for use by both the American Society for Testing Materials and the International Organization for Standardization. Three variations in test conditions reported to be critical in making the test were investigated. These are (1) volume of free space of vacuum vessels, (2) moist and dry air for restoring pressure to atmospheric at the end of equilibration, and (3) slow and rapid rates of restoring pressure with dry air. It was found that, with the type of vacuum vessel used by the Bureau of Mines, none of the variations investigated was critical.

Low-Temperature Carbonization Assay

The laboratory-scale carbonization assay has proved to be a valuable tool in establishing carbonizing properties of different coals and in predicting yields of carbonization products that might be obtained by low-temperature carbonization in pilot- and commercial-scale units. Several types of assay units have been used for this purpose, the original or modified Fischer method being used most generally. Extensive experience with this method indicated that the precise data desired in assaying the lower-rank coals could not be obtained by the conventional Fischer technique. A new low-temperature carbonization assay has been devised that overcomes the objections to the Fischer retort.11/ The assay equipment, shown in figure 2, consists primarily of a welded steel retort, a closely controlled, electrically heated furnace, a liquid condensing and collecting train, a manometric-type gas holder, and a temperature recorder. An automatic pressure regulating device maintains the system at zero pressure or slightly below atmospheric pressure.

Carbonization tests can be made with this apparatus at any desired temperature up to 700° C., and both the rate of heating and final temperature are under close control. The yields of char, tar, light oil, water, hydrogen sulfide, and gas are obtained, with material balances of 100 percent ± 0.3 percent. The distribution of products obtained by the assay of various materials is shown in figure 3.

11/ Goodman, J. B., Gomez, Manuel, Parry, V. F., and Landers, W. S., Low-Temperature Carbonization Assay of Coal in a Precision Laboratory Apparatus: Bureau of Mines Bull. 530, 1953, 24 pp.


LEGEND
A - Temperature recorders
B - Autotransformer
C - Retort heating furnace and case
D - Distillation retort assembly
E - Thermocouples
F - Tar-water receiver, in ice-water bath
G - Tar-mist trap; glass-wool packed
H - Moisture-absorbing tube
I - Hydrogen sulfide absorber
J - Activated carbon trap; light oil
K - Safety traps
L - Gas-recirculation bulb
M - Stainless-steel gasometer
N - Static pressure manometer
O - Pressure regulator
P - Dial thermometer
Q - Stainless-steel wool packing (loose)
Temp. °F X 100
Power supply
VOLTS
(Celite) Insulation
Overflow
Compressed air supply
Liters
Scale
12 inches

GO-118-A

Figure 2. - Modified distillation-assay apparatus (revised).

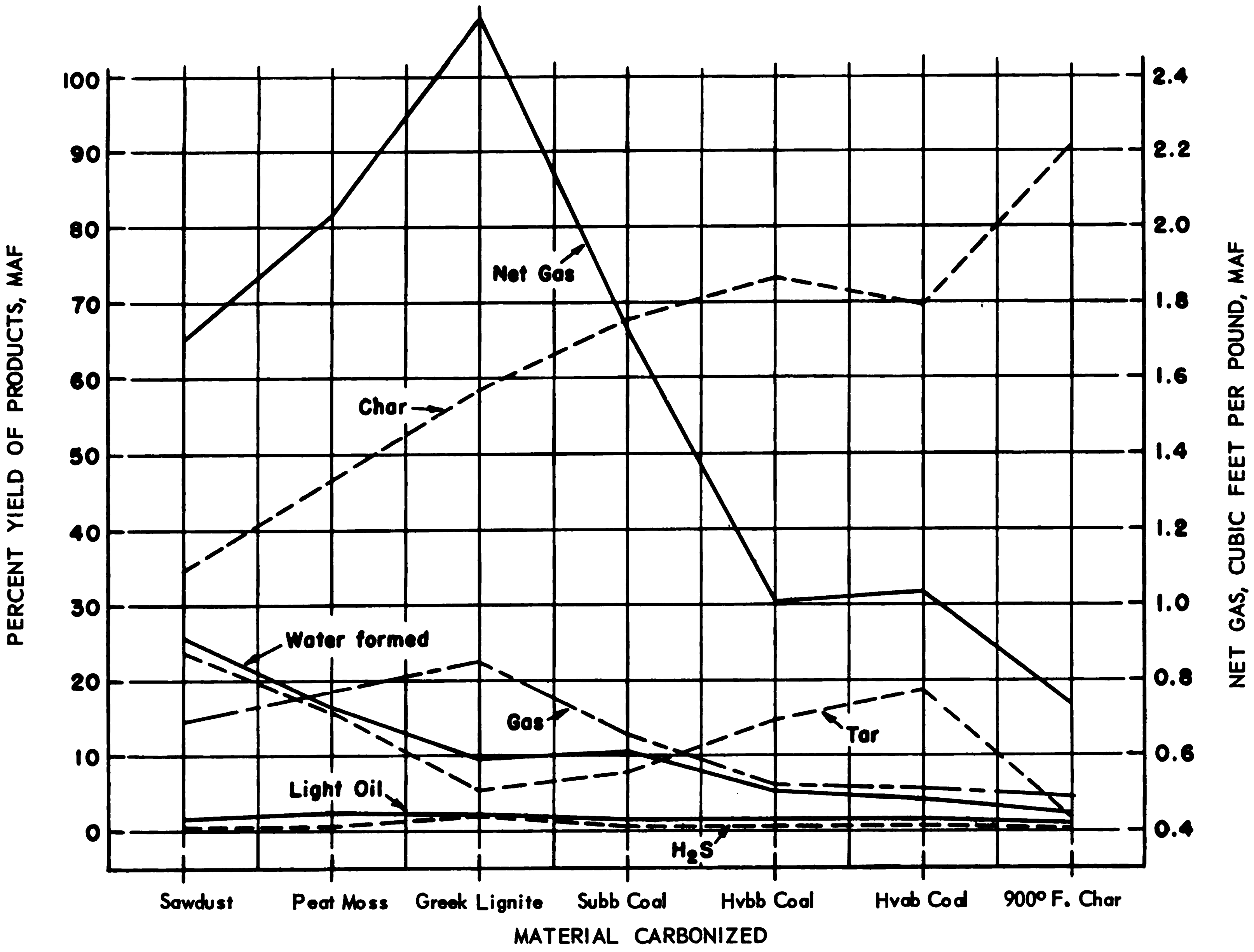


Figure 3. - Distribution of products from various carbonaceous materials carbonized at 500° C.

Analysis of Miscellaneous Materials

Total silica was determined in 294 samples of inert dust currently used for rock-dusting coal mines to determine compliance with Public Law 552, Federal Coal Mine Safety Act, which specifies that rock dust in coal mines shall contain not more than 5 percent total silica. Other samples analyzed or tested in connection with Bureau of Mines investigations of preparation and utilization of coal and of accident prevention included 139 coals and pitch-coke mixtures (for estimating coking properties by the agglutinating-value test), 23 coal and coke ashes, 13 sewage sludges, 13 dusts, and 10 other miscellaneous materials.

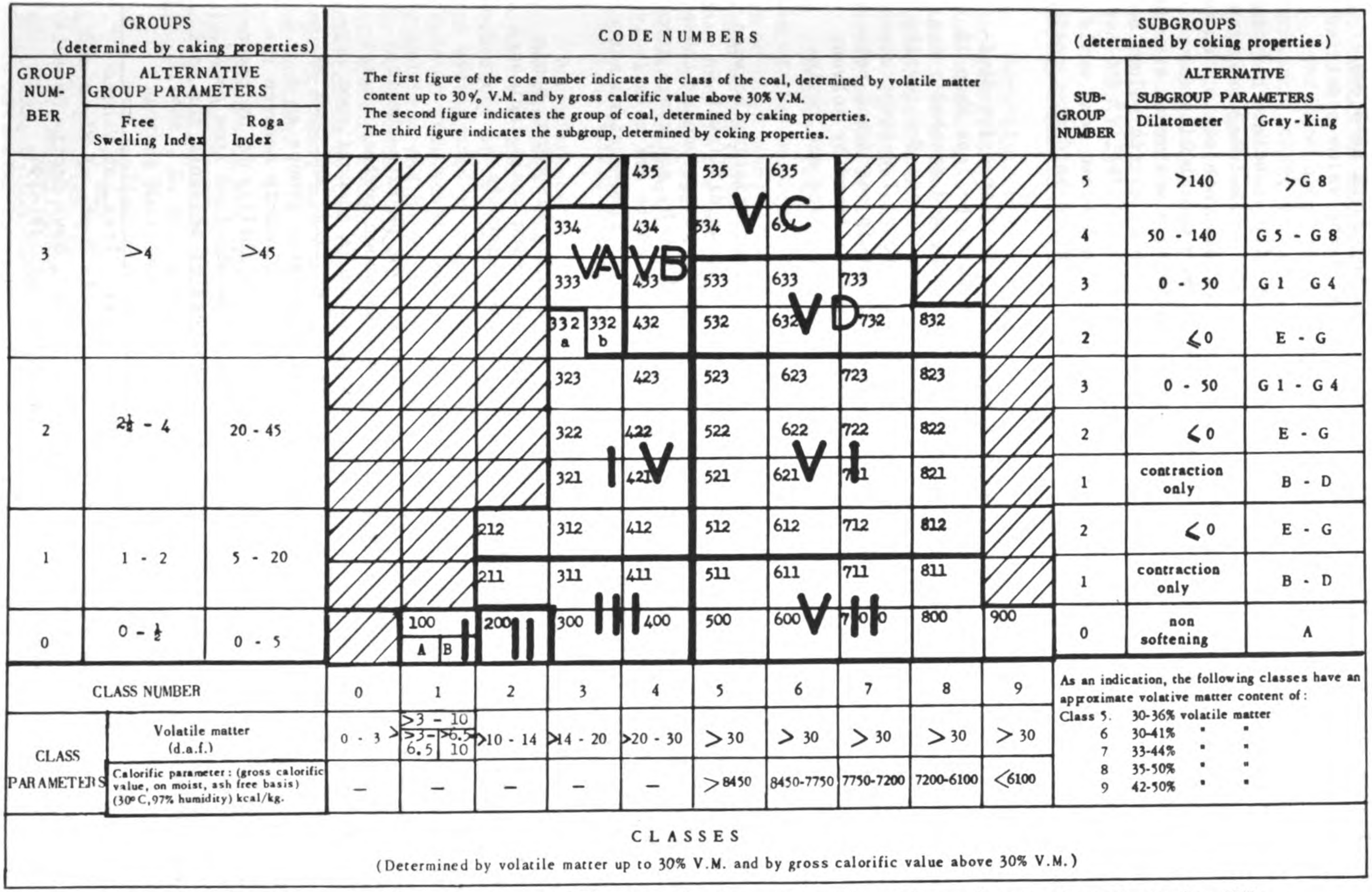
Classification, Constitution, and Petrography

International Classification and Analyses of Coal

The Bureau of Mines continued to cooperate with the Classification Working Party of the Coal Committee, Economic Commission for Europe, in formulating international systems of coal classification. A Bureau of Mines representative has served as a technical expert on the Classification Working Party since its organization in 1949 and has attended 7 of the 11 meetings that have been held. The outstanding achievement to date has been agreement by delegates of all cooperating countries on an International Scientific System of Hard-Coal Classification by Rank. A simplification of this system, whereby coals of generally similar properties are arranged in 10 main groups, is shown in figure 4. The term "hard coal," according to European usage, refers to all coals higher in rank than lignite and brown coal. This system was tentatively agreed upon in November 1953 for commercial classification of hard coals and is to be given a trial period of not longer than 2 years.

From an exchange of information with various interested organizations and coal technologists in the United States, it appears that the proposed simplified system of commercial classification of hard coals (fig. 4) probably will not be adopted for internal use in this country. As American coal fields are distributed over a wide geographical area, economic considerations and the nature of the coal itself often determine its commercial use. Furthermore, for uses such as cokemaking, consumers desire specific information regarding the particular coal under consideration and so would not be satisfied with broad groups of coals of only generally similar properties. At present, the coke industry in the United States is not satisfied to evaluate coking properties of coals using small-scale coking tests, such as dilatometer and Gray-King methods, but wants information supplied by pilot-scale oven tests and finally full-scale coking tests. However, whether or not widely accepted for internal use in this country, this international standard classification for hard coals should prove very useful for comparing American and foreign coals and specifying coals for export.

Considerable progress has been made also in formulating a classification system for brown coals and lignites and in selecting and testing analytical methods for use in establishing parameters for classification of these low-rank coals. The Bureau of Mines evaluated the data obtained during the past 2 years on the exchange samples of 27 typical lignites and brown coals tested from Belgium, Eastern Zone of Germany, Western Zone of Germany, Greece, Italy, Poland, United States, and Yugoslavia. These tests included proximate and ultimate analyses and determination of calorific value, moisture-holding capacity, low-temperature tar yields, extractable waxes and resins, humic acids, megascopic appearance, and petrographic composition. Certain suggestions based on the evaluation were submitted for discussion at meetings of the subgroup of experts on brown coals and lignites held in Geneva, December 1954. They were not made as definite proposals. The pertinent suggestions were:


VA
VB
VC
VD
I
II
III
IV
VI
VII

GROUPS (determined by caking properties)			CODE NUMBERS										SUBGROUPS (determined by coking properties)		
GROUP NUMBER	ALTERNATIVE GROUP PARAMETERS		The first figure of the code number indicates the class of the coal, determined by volatile matter content up to 30% V.M. and by gross calorific value above 30% V.M. The second figure indicates the group of coal, determined by caking properties. The third figure indicates the subgroup, determined by coking properties.										SUB-GROUP NUMBER	ALTERNATIVE SUBGROUP PARAMETERS	
	Free Swelling Index	Roga Index												Dilatometer	Gray-King
3	>4	>45	▨	▨	▨	▨	435	535	635	▨	▨	▨	5	>140	>G 8
			▨	▨	▨	334	434	534	634	▨	▨	▨	4	50 - 140	G 5 - G 8
			▨	▨	▨	333	433	533	633	733	▨	▨	3	0 - 50	G 1 G 4
			▨	▨	▨	332 a 332 b	432	532	632	732	832	▨	2	≤0	E - G
2	2½ - 4	20 - 45	▨	▨	▨	323	423	523	623	723	823	▨	3	0 - 50	G 1 - G 4
			▨	▨	▨	322	422	522	622	722	822	▨	2	≤0	E - G
			▨	▨	▨	321	421	521	621	721	821	▨	1	contraction only	B - D
1	1 - 2	5 - 20	▨	▨	212	312	412	512	612	712	812	▨	2	≤0	E - G
			▨	▨	211	311	411	511	611	711	811	▨	1	contraction only	B - D
0	0 - ½	0 - 5	▨	100 A B	200	300	400	500	600	700	800	900	0	non softening	A
CLASS NUMBER			0	1	2	3	4	5	6	7	8	9			
CLASS PARAMETERS	Volatile matter (d.a.f.)		0 - 3	>3 - 10 >3 - 6.5 / >6.5 - 10	>10 - 14	>14 - 20	>20 - 30	> 30	> 30	> 30	> 30	> 30			
	Calorific parameter: (gross calorific value, on moist, ash free basis) (30°C, 97% humidity) kcal/kg.		—	—	—	—	—	>8450	8450-7750	7750-7200	7200-6100	≤6100			

As an indication, the following classes have an approximate volative matter content of:

Class		
Class 5.	30-36%	volatile matter
6	30-41%	" "
7	33-44%	" "
8	35-50%	" "
9	42-50%	" "

CLASSES

(Determined by volatile matter up to 30% V.M. and by gross calorific value above 30% V.M.)

NOTE: (i) The caking and coking properties should be determined on coal samples with an ash content not greater than 10%. If the ash content of the samples is above 10%, it should be reduced by flotation or any other appropriate process.

(ii) 332a ...>14-16% V.M. 332b ...>16-20% V.M.

Figure 4. - Proposal for an international classification system of hard coals for commercial purposes.

Original from THE OHIO STATE UNIVERSITY

1. Boundary between hard coal and lignites/brown coals suggested as 4,600 kcal./kg. (8,300 B.t.u.) on the moist, ash-free basis. This is the value specified in the ASTM classification system used in the United States.

2. Moisture-holding capacity suggested as a parameter to differentiate between lignites and brown coals. Coals with less than 40 percent moisture-holding capacity would be classified as lignite; those with 40 percent or more, as brown coals. Calorific values on a moist, ash-free basis are suggested as another possibility for dividing the coals into two primary groups. A general relationship was found between calorific values and moisture-holding capacity - coals with high calorific values on a moist basis having a low moisture-holding capacity. If 4,000 kcal./kg. (7,200 B.t.u.) were used as a parameter, the division between lignite and brown coal would correspond, for all practical purposes, with the 40-percent moisture-holding-capacity parameter.

3. Yield of low-temperature tar on a dry, ash-free basis suggested for division of the lignite and brown-coal classes into groups, 1 group to be less than 10 percent tar, 1 to be 10 percent or more but less than 15 percent, and another group to be 15 percent or more. One advantage of using tar yields as a basis for forming secondary groups is their significance in connection with commercial low-temperature carbonization, particularly as practiced in Europe. A relationship was found between tar yields and the amount of waxes and resins (bitumens), as determined by solvent extraction with a mixture of benzene and alcohol. Coals high in waxes and resins gave relatively high tar yields.

4. Physical appearance suggested as being of value in differentiating between lignites and brown coals, although it has the disadvantage of being difficult to describe in terms of a definite parameter. Typical American lignites, such as those from North Dakota and Texas, are compact, relatively hard, and tough, and range from dark brown to black. On the other hand, typical European brown coals are relatively soft, loosely consolidated, light brown to brown, and composed of fine-grained matter when free from woody appearing material.

An investigation of a proposed test procedure for determining bitumens, humic acids, and ligneous and cellulosic substances in lignites and brown coals indicated that additional work is needed to test this scheme of rational analysis.

Problems in Physical Chemistry of Coal

At a conference on the origin and constitution of coal, some physico-chemical data on coal were reviewed critically. Suggestions were made about further experimentation, particularly concerning chemical and structural changes in coal upon drying and their effect on density, sorption of gases, heats of wetting, and optical properties of coal; variation in the relative amounts of oxygenated groups as a function of rank of coal and its correlation with density; relationship between reflectivity of powdered coal and fine porosity as well as susceptibility to hydrogenation; effect of temperature on the X-ray diffraction patterns obtained from coal fractions, especially vitrain; and the change in effectiveness of solvents for coal as a function of pressure and temperature.12/

12/ Storch, H. H., Problems in the Physical Chemistry of Coal: Pres. at Second Conf. on the Origin and Constitution of Coal, Nova Scotia Dept. of Mines and Nova Scotia Research Foundation, June 18-20, 1952; Proc., Nova Scotia Department of Mines, Halifax, 1954, pp. 363-391; discussion, pp. 391-394.

Infrared Spectra of Coal and Other Carbonaceous Materials

Infrared spectra of the anthraxylon portions of many coal samples were compared with each other, as well as with those of asphalt from coal hydrogenation, petroleum asphalt, and gilsonite. Anthraxylons of the same rank produced identical spectra, regardless of source. Differences in rank caused slight changes in the spectra. Variations between spectra of coal and those of the other materials indicated the presence of varying amounts of the same constituents rather than differences in the structural units. The spectra also showed that degradation of bituminous anthraxylon by heating in vacuum produces changes that are comparable with spectral changes caused by differences in rank.[13]

Optical Constants and Molecular Structure of Coal

Recently, optical constants have been used to develop interesting theories concerning the molecular structure of coal.[14] The indexes of refraction and absorption of the vitrinite (anthraxylon) component of coals of various ranks, as determined from reflectivity measurements in different mediums, aided in derivation of an approximate model of coal structure in terms of familiar organic chemical concepts. However, recent results of other investigators appear to cast doubts on the reliability of the reflection method for determining the optical indexes.

Because this appears to be a new and promising method of approach to the problem of the chemical structure of coal, the Bureau of Mines has become interested in these hypotheses. Measurements of reflectivity and optical constants have been begun using photoelectric equipment that provides somewhat more objective results than some of the methods that have been used. Results obtained to date on a series of American coals of different ranks are in fair agreement with those reported on certain European coals.

Coal Petrography and Mineral Matter in Coal

A conference on coal microscopy sponsored by the Coal Petrography Laboratory of the Bureau of Mines was held at the Central Experiment Station, Pittsburgh, Pa., November 8 and 9, 1954. Considerable interest at the meeting centered around the techniques of coal microscopy by reflected light, a method developed in Germany and widely used in countries outside the United States. A display of the newest types of microscopes and optical equipment designed specifically for coal microscopy by American and European firms was made available for inspection to the members of the conference. This was the first meeting devoted solely to coal petrography ever held in this country, and the general interest in this field of coal science is attested to by the fact that 79 representatives of industry, Federal and State organizations, and academic institutions of the United States and Canada attended the meeting.

Review of the literature shows that there are five modes of occurrence of mineral matter in coal:[15]

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[13] Friedel, R. A., and Queiser, J. A., Infrared Spectra of Coal and Other Carbonaceous Materials: Pres. at Ann. Pittsburgh Conf. on Analytical Chemistry and Applied Spectroscopy, March 1954; Spectrochim. Acta (Reports of Meetings), vol. 6, May 1954, p. 244.

[14] Van Krevelen, D. W., (Physical Properties and Chemical Structure of Coal): Brennstoff-Chem., vol. 34, 1953, pp. 167-182.

[15] Parks, B. C., Mineral Matter in Coal: Pres. at 2d Conf. on Origin and Constitution of Coal, Crystal Cliffs, Nova Scotia, June 18-20, 1952; Proc., Nova Scotia Dept. of Mines, Halifax, 1954, pp. 272-292.

1. Impurities of rare and trace elements.
2. Disseminated crystalline mineral matter.
3. Detrital mineral matter.
4. Crystalline mineral matter in fractures, veinlets, petrifications, and nodular masses.
5. Banded impurities.

About 40 of the so-called rare and uncommon elements of coal have been found in ashes of various coals. These rare elements, insofar as known, are not in the form of discrete mineral matter but rather seem to be associated in some way with the organic substance of coal; hence they cannot be identified and evaluated by ordinary petrographic methods. The true mineral substances of coal, however, can be identified and evaluated by special microscopical techniques.

The nature of mineral matter in coal is important and useful in predicting the (1) amount of ash in coal, (2) characteristic of the ash, and (3) improvement that can be expected by coal cleaning. For this reason it is desirable to know the species of minerals present, range of particle or crystal size, and distribution in the coal. The mineral matter in coal may not always be considered an objectionable feature of this natural resource. Coal may become the raw material from which certain rare elements, such as germanium and radioactive materials, are recovered.

A new technique[16/] is being used in a survey of the petrographic composition of the principal commercially delivered lignites of North Dakota. The commercially delivered coals are crushed to minus-1/8-inch size, and selected samples of the crushed lignite are embedded in plastic-bonded plaster of paris. Thin sections are then prepared from the embedded lignite, and these sections are analyzed by the standard Bureau of Mines techniques slightly modified. This technique of analysis of the commercial product of lignite mines yields reliable results with much less effort than is necessary in studying conventional column samples collected at the mine, and the results of the analyses more nearly represent the nature of the coal shipped by the mine.

Two papers were published[17/] [18/] as part of a project in which the nature of the various petrographic (microscopic) types and components of North Dakota lignite and the applications of coal microscopy to various problems of the lignite industry were studied. These papers discussed the methods of coal microscopy, chemical and physical nature of the petrographic components of coal, with special reference to lignite, and various applications of coal microscopy in contemporary industry. Recent developments in German coal microscopy were reviewed, especially the increasing use of petrographic methods in controlling the blending of coking coal in Germany.

Several minor but interesting features of North Dakota lignite have been described and illustrated this year,[19/] for instance the so-called sulfur balls composed primarily of pyrite and gypsum that occur in several North Dakota mines.

[16/] Traverse, Alfred, A Method for the Petrographic Analysis of Commercially Delivered Lignite: Econ. Geol., vol. 49, No. 1, January-February 1954, pp. 92-100.

[17/] Traverse, Alfred, Coal Microscopy, an Important Research Technique: Consulting Eng., vol. 4, No. 1, July 1954, pp. 38-41, 78-79.

[18/] Traverse, Alfred, Applications of Coal Microscopy: Consulting Eng., vol. 4, No. 2, August 1954, pp. 32-35, 74.

[19/] Bureau of Mines, Occurrence and Properties, in Technology of Lignitic Coals, Part I: Bureau of Mines Inf. Circ. 7691, 1954, pp. 33-76.

The occurrence of erratic pebbles of lignite in the glacial drift of North Dakota is briefly discussed in the same publication. Occurrences of lignite pebbles may become geologically important as reference tools of glacial geology and as guides to the direction of glaciation, indicated by the origin of the lignite.

The contributions that the study of microfossils, especially of fossil pollen grains, can make to practical geological work have been reviewed.[20] [21] The abundance of microfossils in lignite should make microfossil study of lignite useful in identifying the lignite beds and for general stratigraphic use in formations where lignite beds occur.

COAL MINING

Study of Known Recoverable Reserves of Coking Coal

During the year known recoverable reserves of coking coal were investigated in Pennsylvania, West Virginia, Kentucky, and Tennessee. Twenty-one reports have been published in the series of county reports giving results of this investigation. Five were published during the reporting period, 2 each for Kentucky and West Virginia and 1 for Tennessee. Figure 5 shows the status of the work in Pennsylvania, West Virginia, Kentucky, Maryland, and Virginia; and figure 6 gives the same data for Tennessee, as of December 31, 1954.

Putnam County, Tenn.

The Wilder (Bon Air No. 2) bed is the only known bed of commercial importance in the county.[22] Remaining reserves in this bed are estimated to be 29 million tons and reserves in beds 28 inches and more thick, 28 million tons. Based on the weighted average recovery in mining of this bed of 61.4 percent, it is estimated that the recoverable reserves are 17 million tons. A map of the Wilder bed is given in the report.

Coal from the Wilder bed is of high-volatile A bituminous rank with moderately high ash and high sulfur content. Since these contaminants cannot be sufficiently reduced by washing, this coal cannot be used to make coke that will meet present chemical standards for metallurgical coke.

Harlan County, Ky.

The two important beds in the county from the standpoint of remaining reserves are the Harlan and Upper Elkhorn No. 3.[23] Reserves for 13 coal beds have been tabulated. As of January 1952 the remaining reserves in all beds are estimated to be 2,138 million tons and reserves in beds 28 inches and more thick, 1,956 million tons.

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[20] See work cited in footnote 19.

[21] Traverse, Alfred, Abs. of The Application of Palynological Methods to Investigations of Tertiary Coals: Micropaleontologist, vol. 8, No. 2, 1954, p. 33.

[22] Williams, L., Lowe, R., Turnbull, L. A., Carman, E. P., Crentz, W. L., Reynolds, D. A., and Abernethy, R. F., Estimate of Known Recoverable Reserves and the Preparation and Carbonizing Properties of Coking Coal in Putnam County, Tenn.: Bureau of Mines Rept. of Investigations 5029, 1954, 21 pp.

[23] Wallace, J. J., Dowd, J. J., Travis, R. G., Abernethy, R. F., and Reynolds, D. A. Estimate of Known Recoverable Reserves of Coking Coal in Harlan County, Ky.: Bureau of Mines Rept. of Investigations 5037, 1954, 26 pp.

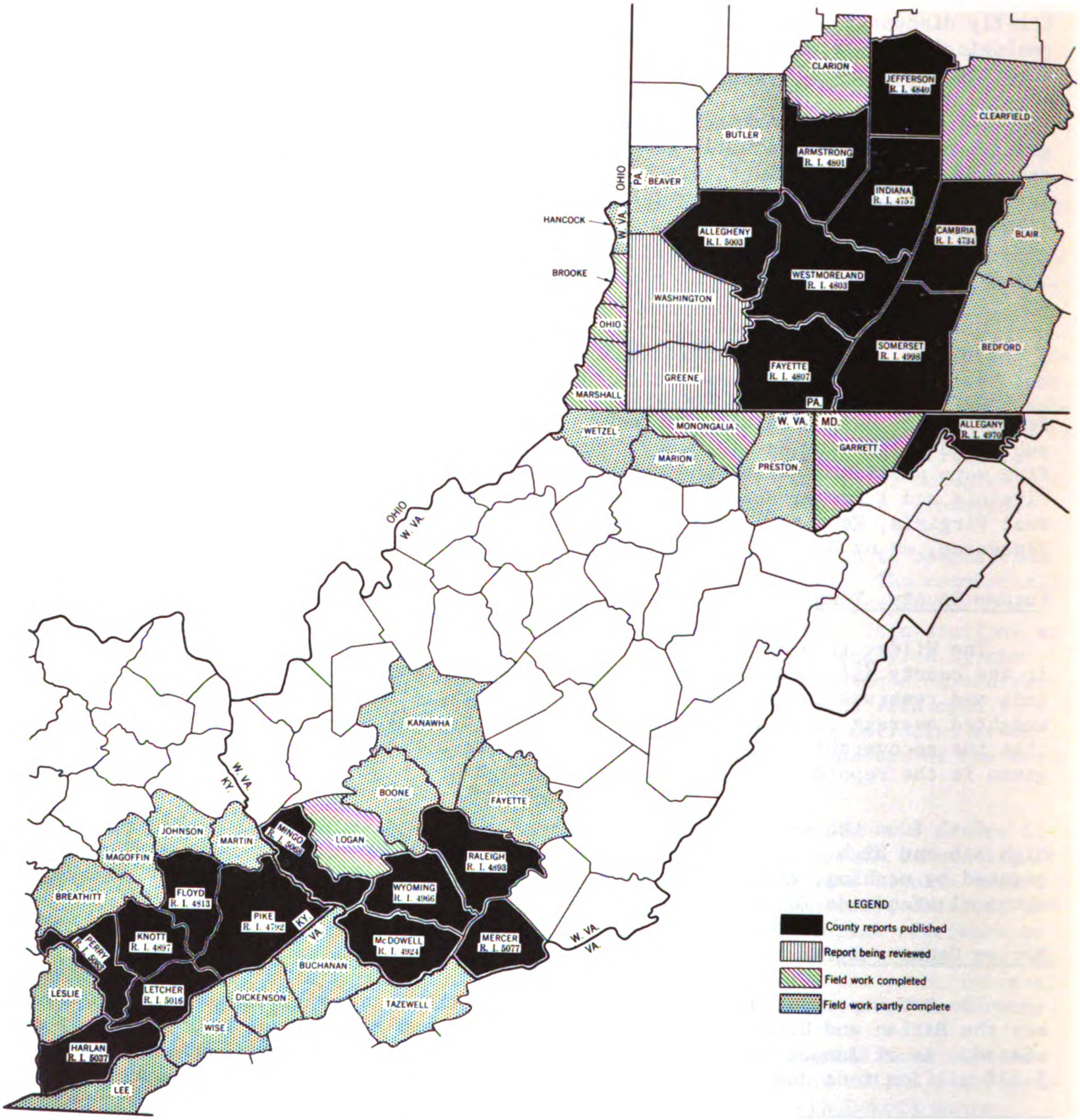

Figure 5. - Status of coking-coal-reserve investigations in Pennsylvania, West Virginia, Kentucky, Maryland, and Virginia, as of December 31, 1954.

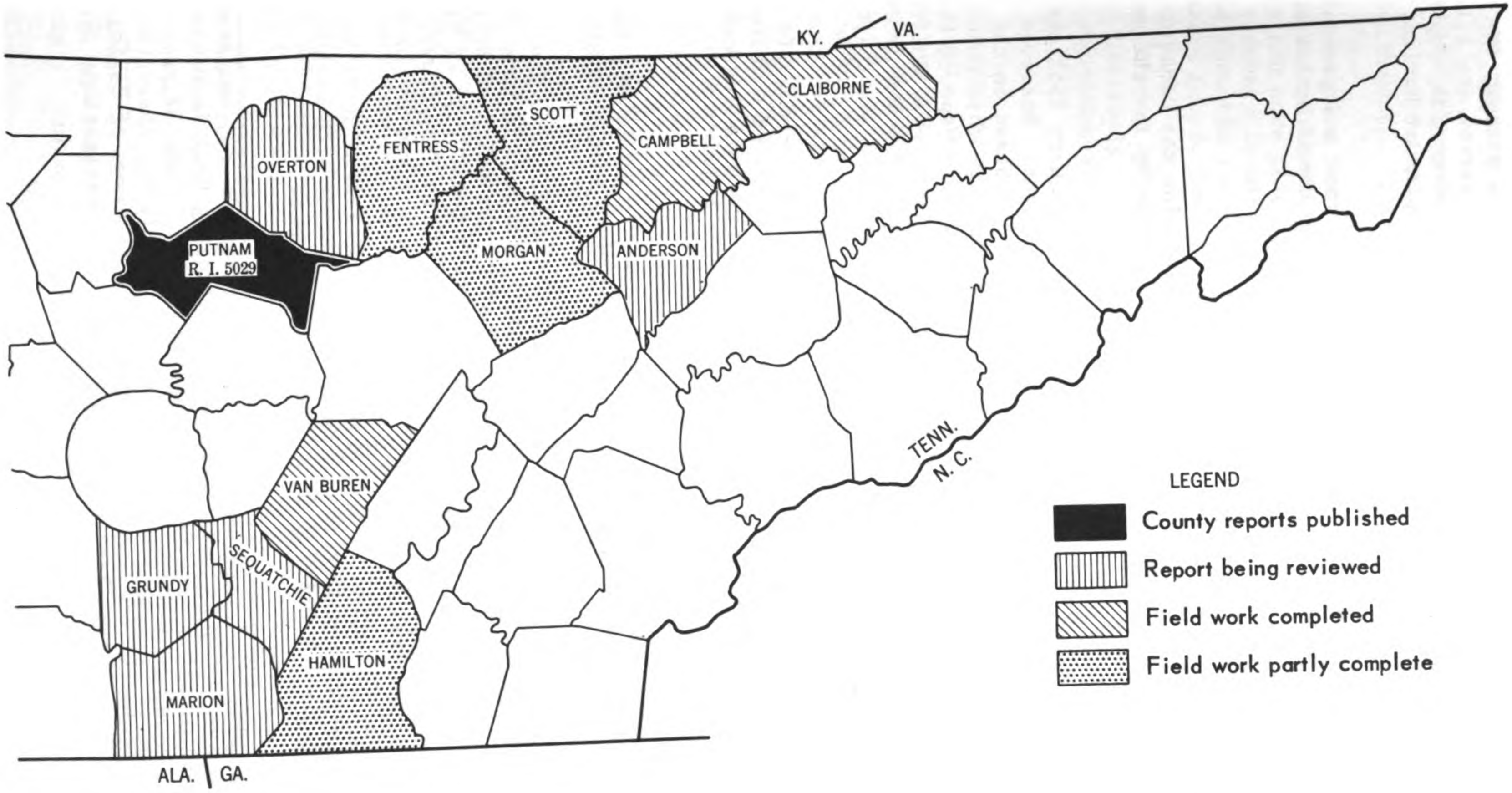

Figure 6. - Status of coking-coal-reserve investigation in Tennessee, as of December 31, 1954.

Based on the weighted average recovery in mining of 57.4 percent for all beds mined in the county, it is estimated that the recoverable reserves are 1,122 million tons. Maps of the Hindman, Flag, Haddix, Wax, Fire Clay, Amburgy, D, Upper Elkhorn No. 3, Elkhorn Leader, Upper Elkhorn No. 2, Harlan, Lower Split of Harlan, and Lower Elkhorn beds are given in the report.

Harlan County coals are high-volatile A bituminous in rank and generally low in ash and sulfur. They yield an excellent metallurgical coke when blended with coals of higher rank.

Mingo County, W. Va.

From both a production and recoverable reserve standpoint the Cedar Grove and Alma beds rank 1 and 2, respectively. The Cedar Grove bed is by far the more important.24/

Reserves have been tabulated for 19 coal beds. As of January 1953 the remaining reserves in all beds are estimated to be 3,007 million tons. Reserves in beds 28 inches or more thick are estimated at 2,396 million tons. Based on the weighted average recovery in mining of 57.0 percent for all beds mined in this county, it is estimated that the recoverable reserves are 1,365 million tons. Maps of the No. 5 Block, Stockton, Coalburg, Little Coalburg, Buffalo Creek, Winifrede, Chilton "A," Chilton, Hernshaw, Williamson, Upper Cedar Grove, Upper Split of Cedar Grove, Cedar Grove, Lower Cedar Grove, Alma, No. 2 Gas, Eagle, Bens Creek, and Lower War Eagle beds are given in the report.

Mingo County coals from the major-producing beds are of high-volatile A bituminous rank. Generally low in sulfur and ash, these coals yield an excellent metallurgical coke when blended with moderate proportions of low-volatile coal.

Mercer County, W. Va.

From the standpoint of present production and recoverable reserves, the Pocahontas No. 3 and Pocahontas No. 6 are the most important beds in the county.25/

Reserves have been tabulated for eight beds. As of January 1953 the remaining reserves in all beds are estimated at 188 million tons. Reserves in beds 28 inches and more thick are estimated at 80 million tons. Based on the weighted average recovery in mining of 65.4 percent for all beds mined in this county, it is estimated that the recoverable reserves are 52 million tons. Maps of the Fire Creek, Pocahontas No. 9, Pocahontas No. 6, and Pocahontas No. 3 beds are given in the report.

Coal from the major-producing Mercer County beds is of low-volatile bituminous rank. Owing to the expanding properties of these coals, blends with high-volatile coals usually are made for carbonizing in slot-type coke ovens.

24/ Wallace, J. J., Dowd, J. J., Tavenner, W. H., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Mingo County, W. Va.: Bureau of Mines Rept. of Investigations 5068, 1954, 57 pp.

25/ Wallace, J. J., Dowd, J. J., Tavenner, W. H., Provost, J. M., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Mercer County, W. Va.: Bureau of Mines Rept. of Investigations 5077, 1954, 20 pp.

Perry County, Ky.

From the standpoint of present production and recoverable reserves, there are two beds of major importance - Flag and Fire Clay - and two of minor importance - Haddix and Hindman. The Fire Clay bed has the largest known recoverable reserve.26/

Reserves have been tabulated for seven coal beds. As of January 1954 the remaining reserves in all beds are estimated to be 840 million tons. Reserves in beds 28 inches and more thick are estimated at 720 million tons. Based on the weighted average recovery in mining 56.0 percent for all beds mined in this county, it is estimated that the recoverable reserves are 403 million tons. Maps of the Hindman, Flag, Hazard No. 6, Haddix, and Fire Clay beds are given in the report.

Perry County coals from the major producing beds are high-volatile A bituminous in rank. Generally low in ash and sulfur, these coals must be blended with low-volatile expanding coals to yield a good grade of metallurgical coke.

Coal Investigations in Alaska

The Alaska coal program includes both short- and long-range objectives essential to supply immediate fuel requirements and to promote the orderly economic growth of the Territory. Field work is being carried out in close cooperation with the Federal Geological Survey.

Since known reserves of subbituminous coal in the Healy River field, the principal source of supply for the Fairbanks area, are believed to be adequate for immediate needs, major efforts have been directed toward development and increasing production of bituminous coal from the Matanuska field. This field supplies the Anchorage and lower rail-belt area. Principal production has been from one mine with limited developed reserves, although the total reserves of the field are potentially large.

During 1954 work by the Bureau of Mines was again concentrated on the western part of the Wishbone Hill syncline of the Matanuska field in the vicinity of the old Buffalo and Premier mines. Four additional holes were drilled on contract in line across the synclinal axis. These indicated continuity of the coal-bearing formations for over 4,000 feet southeast from the Buffalo-mine workings. Two of three holes drilled previously (in 1953) penetrated both the Jonesville and Premier series of coal measures, thus greatly increasing the indicated reserves; only the Premier series had been previously developed. However, in 1954 the holes drilled were stopped at well-defined marker beds, and the continuity of the north limb and the approximate location of the synclinal axis were inferred from geologic evidence obtained from the drill cores. The south limb of the syncline in this area has not been explored and may contain additional large reserves of good-grade coal. Coal from the Buffalo area is of higher rank and commands a better market than that from other parts of the field.

Angledozer trenching and drilling of one hole established the position of the Premier series north of the Premier fault and increased the possibility of developing a minable block of good coal in this area.

26/ Wallace, J. J., Dowd, J. J., Travis, R. G., Abernethy, R. F., and Reynolds, D. A., Estimate of Known Recoverable Reserves of Coking Coal in Perry County, Ky.: Bureau of Mines Rept. of Investigations 5083, 1954, 26 pp.

Foreign Coal Investigations and Technical Assistance

During 1954, under the United States Government program of technical assistance to underdeveloped areas, the Bureau of Mines gave technical assistance on coal projects in five foreign countries: Afghanistan, Colombia, India, Pakistan, and the Philippines. This work was carried on in cooperation with the Foreign Operations Administration. In Pakistan the work was in connection with construction of an ammonium sulfate fertilizer plant, using coal to produce the necessary ammonia. The other projects were aimed at increasing local coal production to conserve foreign exchange and to raise the general standard of living.

Afghanistan

Efforts of the two Bureau engineers assigned at the request of the Afghan Government to assist the small but vital coal-mining industry of Afghanistan had two objectives: (1) To increase coal production and develop mines for a target annual output of 60,000 tons; and (2) to establish safety practices in the mines. Production at the 2 active mines, Kar Kar and Ishpusta, has increased to about 18,000 tons annually through more efficient mining practices and by the installation of a mechanical hoist in the Ishpusta mine. To attain the 60,000-ton objective, mining plans were prepared for the Kar Kar mine, proposing a room-and-pillar system of extraction. A powerline survey was made to permit bringing available electricity from a hydroelectric plant to the mine.

Preliminary reconnaissance of the Darra Suf coal deposit was begun also. This is an area that has promise for the limited economy of Afghanistan. However, the area is isolated and the problem of transporting coal from Darra Suf to Kabul, the largest consuming center, or to a proposed cement plant will require expensive road building. Because there appears to be no other means of meeting the long-term solid-fuel requirements of Afghanistan, the Ministry of Mines of Afghanistan is now considering the development of Darra Suf and the construction of the necessary access road.

A safety code for the coal mines was drafted with the assistance of Bureau engineers and put into effect in midyear. Emphasis was placed on better ventilation and on the training of Afghan mining engineers, firebosses, and mine foremen. In addition, instruction in first aid is being given by one of the Bureau representatives.

Colombia

A large coal-preparation plant to wash 330,000 tons of coal a year is under construction near Cali, Colombia. Local Cauca Valley coals are being mined at the rate of 250,000 tons a year, and the production of mines now in operation is being expanded to supply the preparation plant. A Bureau of Mines engineer stationed in Cali has made recommendation to individual mine operators on ways of increasing production at the mines that are to supply the new washing plant.

India

The Bureau of Mines is concerned with two fuel projects in India, the lignite deposit of South Arcot and the Damodar Valley deposit northwest of Calcutta. In the South Arcot project the test pit was excavated to a depth of about 145 feet, nearly 30 feet short of the top of the lignite. Completion of the pit was delayed by late arrival of the necessary pumping and drilling equipment. In spite of heavy monsoon rains the open-pit walls have stood up very well, and no mining difficulty is anticipated from landslides. Based upon drilling data, the Bureau of Mines engineer is of the opinion that the water table can be lowered enough to avoid the danger of flooding when the pit is in operation. Further pumping and drilling are planned to settle this important phase of the mining problem.

Confirmation of the Bureau's development proposals and of the economic feasibility of the project was supplied by a British firm engaged by the Government of India to study all available information and to submit proposals for mining and utilization of the lignite, as well as for economic schemes for generating electricity.

Detailed plans for mechanized coal mining at Bermo, Bihar, in the Damodar Valley northwest of Calcutta, have been submitted to the Indian Government by the Bureau of Mines advisor who believes that diesel-powered draglines and trucks would result ultimately in the greatest economy. Indian engineers, on the other hand, believe that both the availability of electric power nearby and the cost of importing diesel fuel indicate that electrical equipment should be installed. The work done there by the Bureau has brought a fresh concept that may influence practice and lower mining costs.

Pakistan

During the year considerable progress was made on design and procurement of equipment for the 50,000-ton-per-year Mari Indus (Daud Khel) ammonium sulfate fertilizer plant. A Bureau of Mines engineer served as technical advisor and representative for the Foreign Operations Administration at the offices in Brussels of the engineering firm that is designing and installing the plant. The plant will utilize local noncaking coal to manufacture synthesis gas by the Lurgi process. Hydrogen from the gas will be combined with nitrogen from the atmosphere to produce ammonia, which will, in turn, be reacted with locally mined gypsum and carbon dioxide to produce ammonium sulfate. Total cost is estimated at about U. S. $18,000,000, of which the United States Government is contributing about two thirds. Toward the end of 1954 over 90 percent of the equipment had been ordered, and one-third of this had already arrived at the site at Pakistan.

Philippine Islands

Among the more important of the many coal fields in the Philippines are the Malangas field on the southern island of Mindanao, several areas on the island of Cebu, and deposits of subbituminous coal on Batan Island. The Malangas area, although smaller in estimated reserves than Cebu, contains the highest rank coal so far investigated. A Bureau of Mines engineer in the Philippines concentrated his efforts on the Malangas field to suggest the location of additional diamond drilling for determining recoverable reserves.

Successful coking tests of Malangas coal and blends of this coal with Cebu coals were completed in Bureau of Mines laboratories in Pittsburgh. Fluid bed drying and carbonizing tests of lower rank Philippine coals were completed in the Bureau of Mines Denver laboratories and pilot plant. These latter tests showed that the dried coal is a suitable fuel for industrial uses, particularly for steam raising and cement burning. Internal reports of the results of all testing work were distributed to the Foreign Operations Administration and to interested agencies in the Philippines, and publication as a Bureau report is planned.

Mining Methods and Practices

Anthracite-Mining Research

Upon completion of the initial cooperative experimental work with the Bureau of Mines pneumatic packing machine reported last year,[27] the equipment was transferred to an area where immediate removal of coal pillars was contemplated. (See fig. 7.) The machine operated 159 shifts over a period of 10 months, and 26,000 tons of breaker refuse was packed into 20 chamber voids. The average rate of material handling was 36.7 tons per hour. Material was blown by compressed air through a 6-inch steel discharge line for distances varying from a few hundred feet to a maximum of 1,310 feet from the packing machine. The machine was removed from the working area in November 1954, when the original mining plans were changed by the cooperating company and packing work by this method was discontinued. A report covering this second phase of the work is in preparation.

Experiments with Bureau-owned Becorit collapsible steel props (see fig. 8) have been carried on over a 2-year period, and the initial phase has been completed. The problem was to determine a method to insure safe and efficient mining of thick coal pillars in flat-bed areas under water-bearing sands, in improved surface areas, and/or under thick, strong layers of overlying rock having a tendency to produce squeeze conditions when pillars are removed. Experience shows that the roof can not be controlled properly by conventional wood-timbering-and-propping methods. The theory advanced, and proved by the experiment, stresses advantages in safety, recovery, and efficiency to be gained by permitting the roof to subside gradually and evenly over a wide area. It is believed that this type of roof action is attainable only by using yielding supports and backfill. During this experiment 25,000 tons of run-of-mine coal was removed. Convergence as great as 8 inches did not affect the immediate roof, and output per man-shift was increased 40 percent. Recovery of pillar coal was 90 percent.

A vibrating-blade coal planer has been designed and provided by the Bureau of Mines for mining and loading coal without drilling or blasting. (See fig. 9.) As the machine is pulled along the face the coal is sheared from the solid by four pneumatic hammers and loaded onto a conveyor. Since November 1953 preparations have been underway to test the planer in an underground anthracite mine near Wilkes-Barre, Pa. The cooperating company has been preparing the underground test site, and necessary auxiliary equipment has been purchased. For this test an armored face conveyor has not been provided to remove the coal after it has been sheared because the primary object of the test is to ascertain whether the machine will plane coal as hard as anthracite. Installation of the machine underground was nearing completion at the end of the year, and testing was planned to begin in February 1955.

Bituminous-Coal-Mining Research

The introduction in recent years and the use of continuous mining machines that cut and load coal from the solid in one operation without drilling and blasting have been among the most significant developments in the long history of underground coal mining. The Bureau of Mines has studied the use of three principal types of

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[27] Brown, R. L., and Carman, E. P., Report of Research and Technologic Work on Coal and Related Investigations, July 1, 1952, to December 31, 1953: Bureau of Mines Inf. Circ. 7699, 1954, 102 pp.

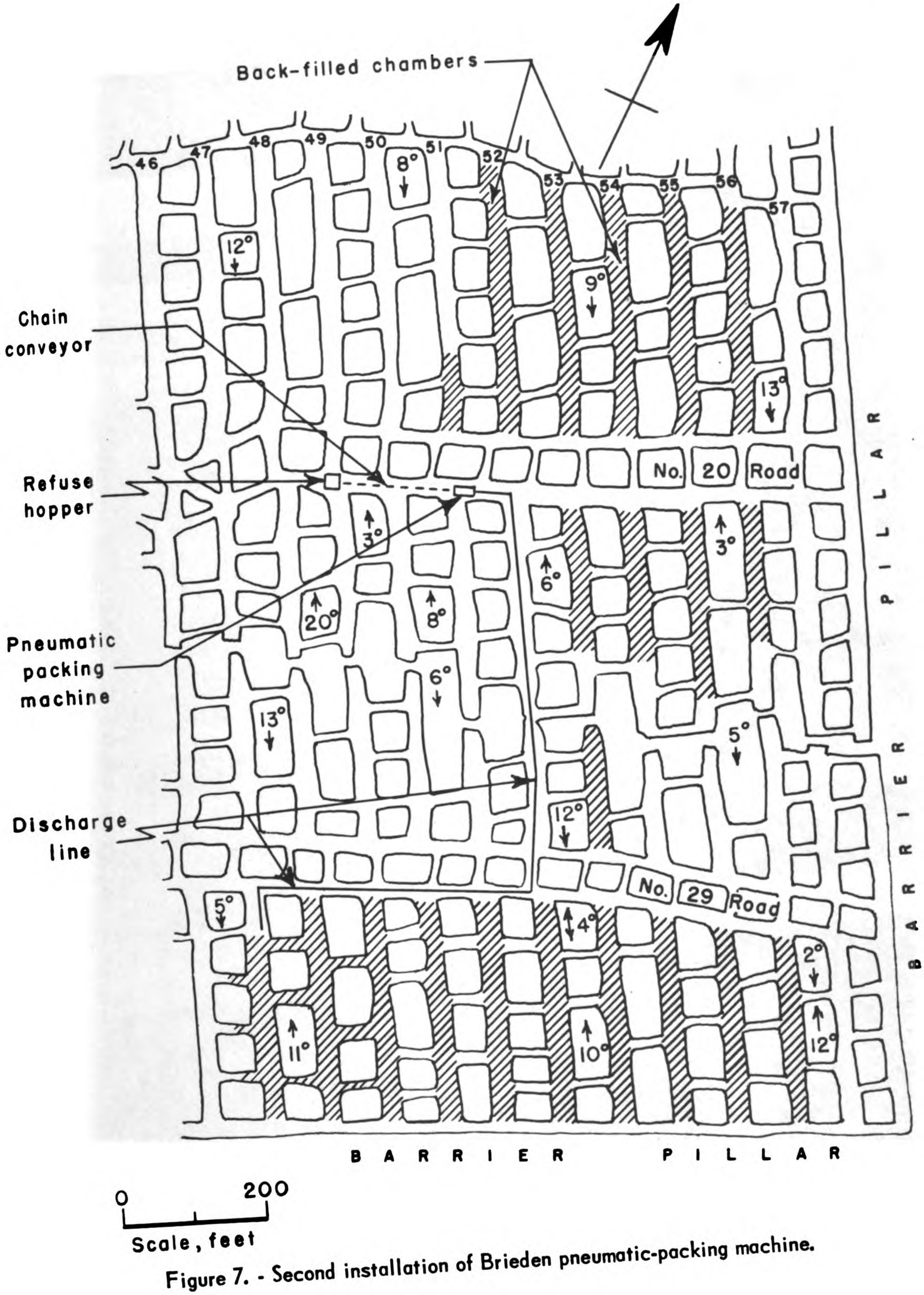

Figure 7. - Second installation of Brieden pneumatic-packing machine.

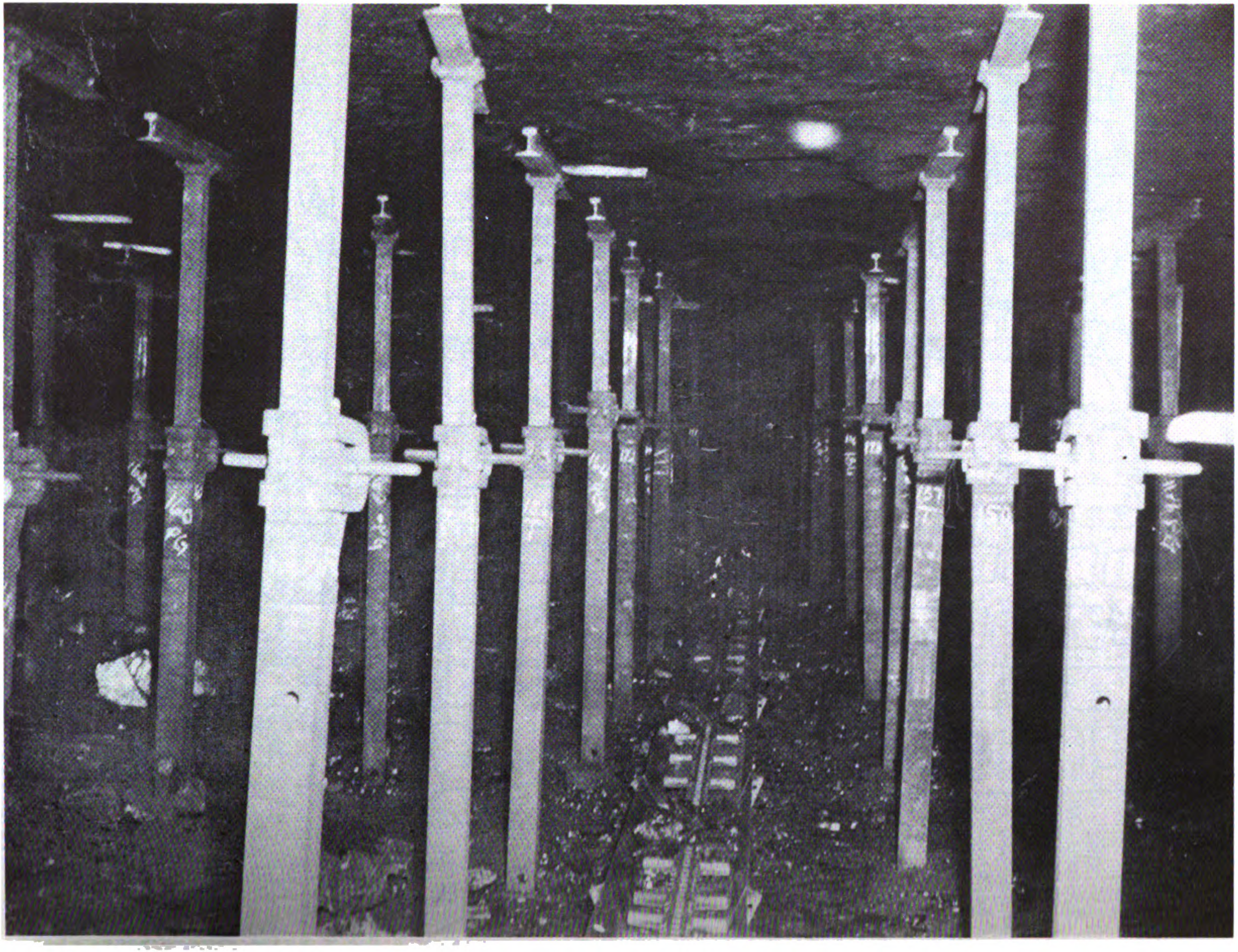

Figure 8. - Installation of yielding steel props (Becorit).

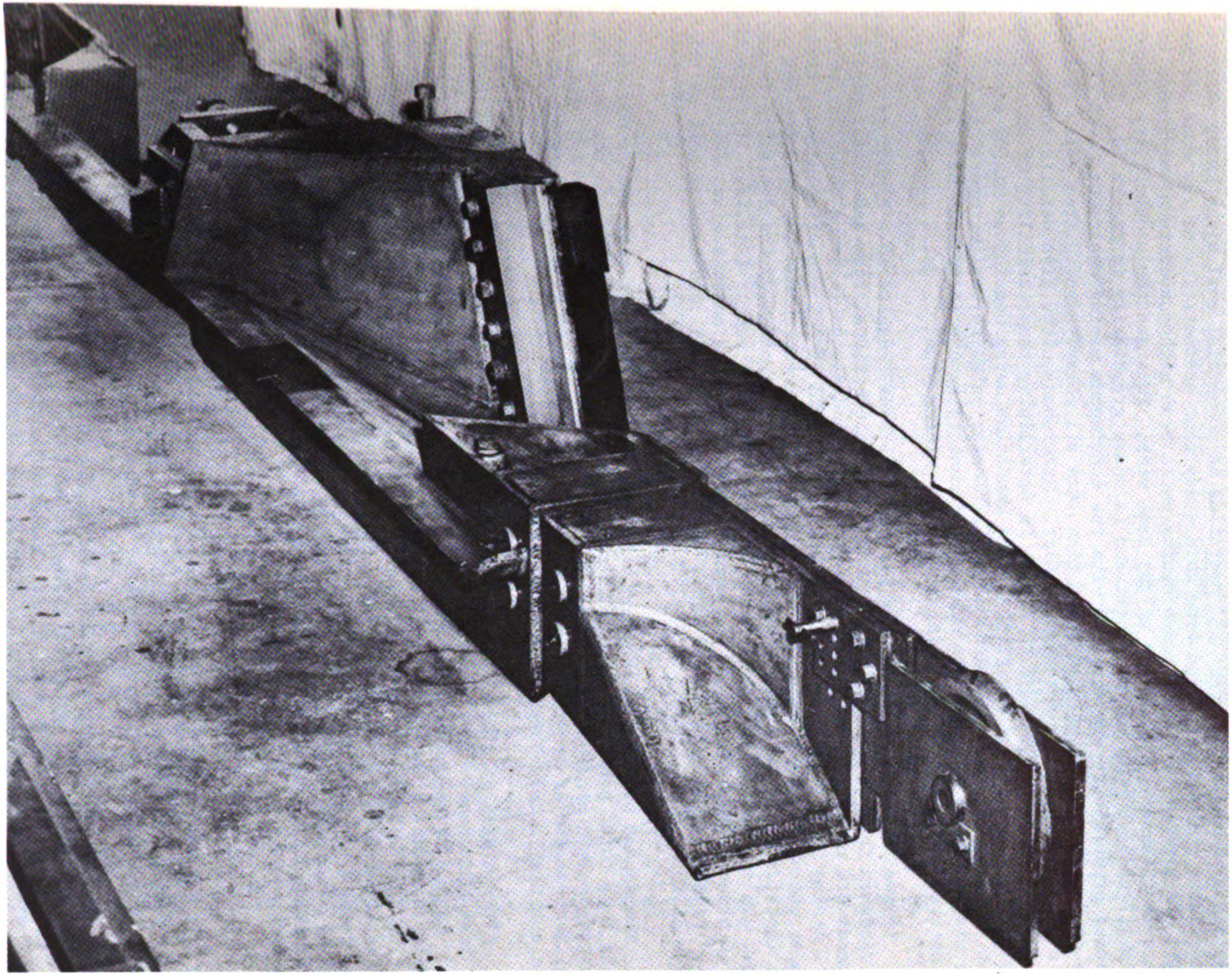

Figure 9. - Bureau of Mines vibrating-blade coal planer.

continuous mining machines[28] [29] operating in commercial coal mines under various conditions. It was concluded from this study that productivity of raw coal per man shift was greater with continuous mining units than with conventional equipment in the same thickness of coal and at the same mine. This greater productivity ranged from 2.7 to 45.3 tons per man shift and is shown graphically in figure 10. The increased productivity was attained with the continuous mining equipment, even though the productive operating time (face time less all delays) ranged from a low of 2.58 to a high of 5.67 hours per 8-hour shift. References cited give details for each of the 20 operations studied to assist in determining the feasibility of developing a plan of operation for any given mining condition using continuous mining equipment. This study is believed to be of particular value to smaller operators who may wish to install continuous mining equipment to reduce costs, but have limited or no research funds to determine a workable mining plan.

Longwall mining, particularly in thin coal beds, results in a higher percentage of recovery than is ordinarily obtainable when conventional room-and-pillar mining methods are used. Increased interest in the United States is being shown in longwall mining with the German coal planer. At the end of the reporting period, three planer units had been operated in this county, and a fourth was imported but not yet installed. To date 589,000 tons of coal has been mined by the 3 planers in use here. On completing mining in three adjacent longwall panels (see fig. 11) with the first planer installation,[30] the equipment was moved to another mine, where the third panel is now being mined. This planer had mined 291,000 tons of coal by the close of 1954.

The second planer installation has mined 122,000 tons of coal and is now operating in a third panel. The coal at this mine is "burned" (sticks) to the top, and blasting before planing and air picks are used to loosen the upper portion of the coal bed because of its tendency to overhang the conveyor, as shown in figure 12, thus creating a hazardous condition.

After mining of 176,000 tons of coal operation of the third planer installation has been temporarily recessed while details of a change in mining method are worked out. Mining in the unfinished panel was completed by the conventional method. Two panels adjacent to the first panel are being developed. Conventional mining methods will be used to mine the inby 600 feet in each new panel, after which the planer will be installed in panel 2. Mining in panel 3 by conventional room-and-pillar methods will retreat at the same rate as the longwall face in panel 2, so that more weight will be placed on the longwall coal face by breaking a thick sandstone member of the overburden that is believed to have been the source of roof-control difficulty in the first panel.

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[28] Shields, J. J., Magnuson, M. O., Haley, W. A., and Dowd, J. J., Mechanical Mining in Some Bituminous Coal Mines. Progress Report 7. Methods of Mining With Continuous-Mining Machines: Bureau of Mines Inf. Cir. 7696, 1954, 118 pp.

[29] Mining Congress Journal, Methods of Mining With Continuous-Mining Machines: Vol. 40, No. 12, December 1954, pp. 62-66.

[30] Haley, W. A., and Quenon, H. A., Modified Longwall Mining With a German Coal Planer. Progress Report 2. Completion of Mining in Three Adjacent Panels in the Pocahontas No. 4 Bed, Helen, W. Va.: Bureau of Mines Rept. of Investigations 5062, 1954, 13 pp.

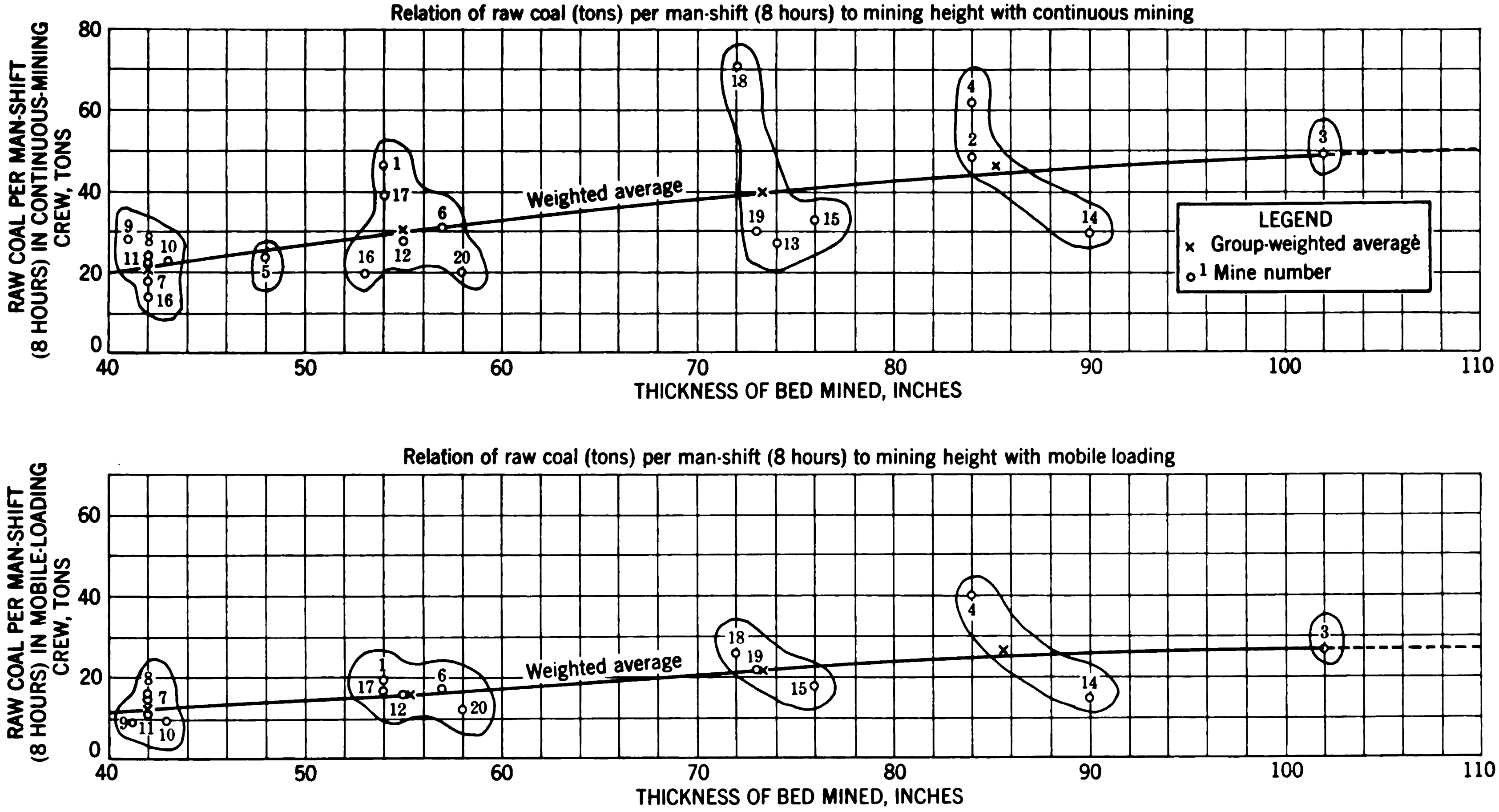

Figure 10. - Comparison of productivity of continuous-mining machines and mobile-loading equipment.

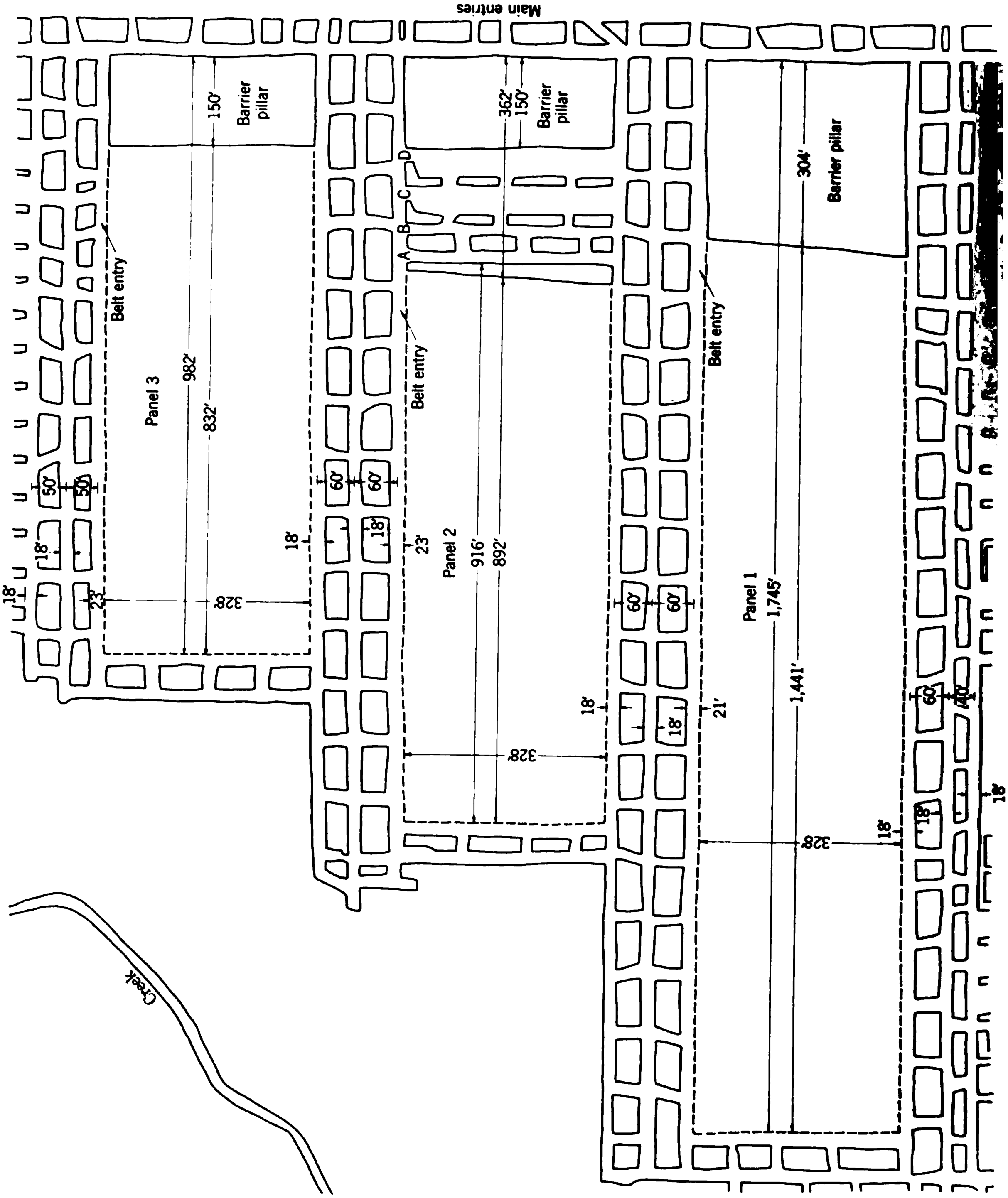

Figure 11. - Plan of three panels mined with planer.

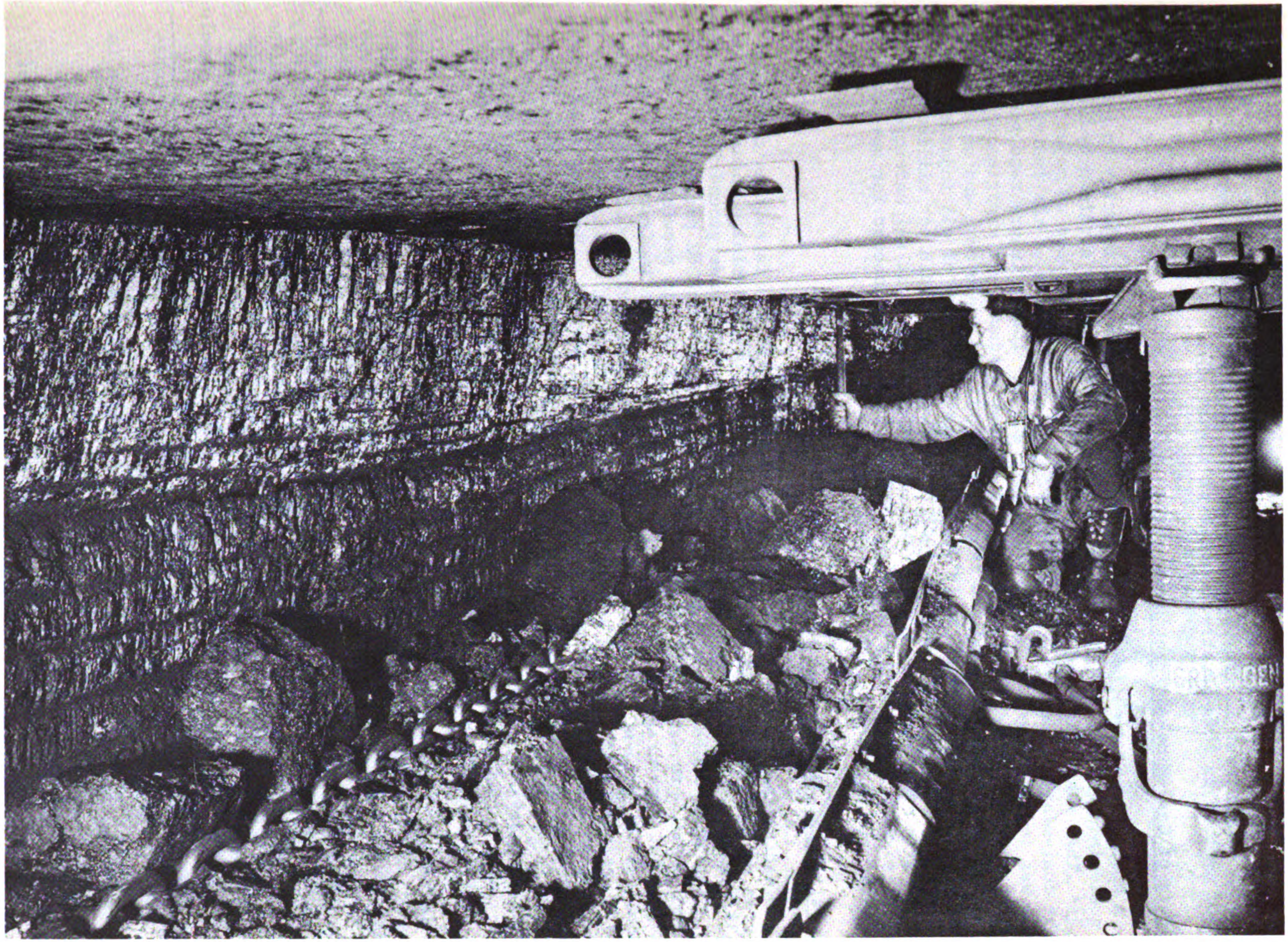

Figure 12. - Propfree face when mining with coal planer; top coal overhanging conveyor where coal sticks to roof.

Operation of a continuous-type mining machine on a longwall face in Nova Scotia was studied by Bureau engineers.[31] Mining conditions were more severe than are generally encountered in the United States. A suggested plan of operation for this type of machine in this country is shown in figure 13.

Analysis of Coal-Mine-Accident Data

A complete and detailed statistical report on deaths and injuries to persons in the coal-mining industries for 1950 shows the best record yet attained by the industry.[32] This was the second consecutive year in which there were no major disasters in the coal-mining industry. The increase in relative safety of the individual employee was indicated by the lowest death rate and the lowest injury rate per million man-hours of exposure and per million tons of coal produced yet experienced in the coal industry. Accidents resulted in the deaths of 643 employees, and an additional 37,264 employees were injured in 1950. The average severity of all injuries was 154.6 days lost per injury, and the fatality rate was 0.9 death per million man-hours. Falls of roof and face were the cause of two-thirds of all underground fatalities and a fifth of the injuries. Haulage accidents account for one-fifth of the deaths and injuries in the year reported.

Roof-Fall Fatalities in Coal Mines

Investigations by the Bureau of Mines of 225 of the 232 fatalities caused by falls of roof, face, and rib, charged to the bituminous-coal-mining industry during 1953[33] showed that 67 percent of all fatalities occurring underground in bituminous-coal and lignite mines resulted from this cause compared with 62 percent for 1952. Although there were fewer roof-fall accidents in 1953 than in previous years, an increase in the percentage of total fatalities from this cause indicates more successful control of accidents from other causes than those involving roof falls. Human failure was responsible for 83 percent of the fatalities, with unforeseen dangers and unavoidable risks accounting for the remaining 12 percent. Reports on 64 underground fatalities in the anthracite mines of Pennsylvania in 1953[34] showed that roof-fall accidents were increasing in those mines. Two-thirds of the 64 fatal accidents was charged to falls of roof, face, or rib. Gas explosions caused 5 deaths; and haulage, inrush of water, and falling caused 3 each. Other causes were electricity, explosives, machinery, and miscellaneous accidents.

Recommendations for preventing and reducing the incidence of roof-fall accidents include: (1) Minimum standards for systematic roof support suited to the conditions and the mining system of each mine should be adopted and followed regardless of roof conditions; (2) supervisors should be given safety training; (3) roof, ribs, and face of places where men work or travel should be inspected as often as necessary and dangerous conditions promptly corrected; (4) permanent timbers should not be removed by hand; (5) roof bolting should be adopted where practicable; (6) loose roof should be taken down, by blasting if necessary; (7) danger signs should be posted where areas have been abandoned or men have been withdrawn because of bad roof; (8) employees should cooperate fully in observing a timbering plan; (9) dangerous conditions should

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[31] Stahl, R. W., and Dowd, J. J., Mining With a Dosco Continuous Miner on a Longwall Face: Bureau of Mines Inf. Circ. 7698, 1954, 11 pp.

[32] Reese, S. T., Wrenn, Virginia E., and Reid, Elizabeth J., Injury Experience in Coal Mining, 1950: Bureau of Mines Bull. 540, 1954, 64 pp.

[33] Bureau of Mines, Falls of Roof, The No. 1 Killer at Bituminous-Coal Mines, 1953: Bureau of Mines HSS 427, Mineral Industry Surveys, 1954, 12 pp.

[34] Mather, J. V., Fatalities at Pennsylvania Anthracite Mines, 1953: Bureau of Mines HSS 426, Mineral Industry Surveys, 1954, 19 pp.

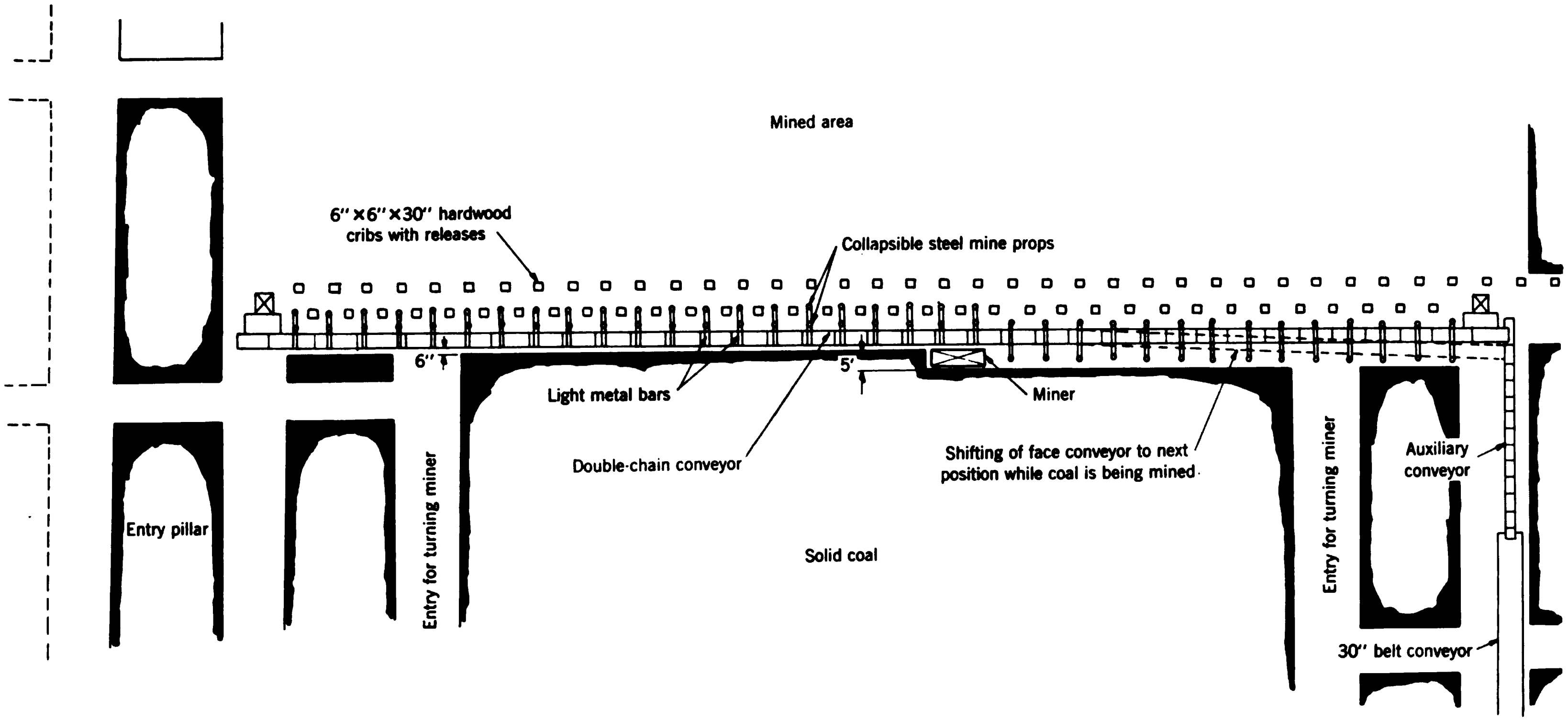

Figure 13. - Suggested plan for longwall mining with a Dosco continuous miner in a flat-lying bed.

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be corrected promptly or men should withdraw and notify their supervisor; (10) employees should attend training classes; and (11) roof supports should not be removed to facilitate loading or to allow movement of equipment unless equivalent protection is provided by installing other supports.

Haulage Fatalities in Coal Mines

An analysis, following investigation of 88 of the 92 haulage fatalities charged to the bituminous-coal-mining industry in 1953, covered 75 underground and 13 surface accidents.35/ Accidents at strip mines and others not considered representative were not included. Fatal haulage accidents occurred in 12 States and Alaska; 61 percent occurred on haulage roads, 18 percent in face areas, 6 percent on slopes, and 15 percent on the surface. The most frequent kinds of accidents were: Caught or struck by moving equipment, injured by collisions, runaway equipment, and contact with low roof, crossbars, face, or rib. The job experience of the victims showed, as in previous studies, that persons operating strange equipment or acting in unfamiliar jobs are prone to serious injury regardless of their accumulated years of mining experience. Twenty-nine percent of the victims were employees not normally considered haulage employees or seldom exposed to haulage hazards.

Some form of physical or operating hazard was evident in 43 percent of the accidents and was considered the primary cause of 32 percent. Unsafe practices, either involuntary acts or deliberate chance taking, were evident in 61 percent of the accidents and were considered the primary cause of 49 percent. Unsafe practices, combined with physical hazards and undetermined causes, were responsible for the remaining 19 percent. Thus, unsafe physical conditions, unsafe practices, or a combination of both must be recognized, avoided, and corrected to obtain effective accident prevention. The Bureau of Mines recommends that transportation employees be selected on the basis of physical ability, mental qualifications, and stability; that job training and certification be established; that reasonable safety rules be promulgated to govern the actions of haulage employees; that the haulage system be planned on the basis of present and future requirements; that a preventive-maintenance program be observed; that a positive communications and control system be established; and that employees comply with instructions and correct defective conditions.

The Bureau of Mines has compiled and published recommendations and specifications36/ for the proper construction and maintenance of track-haulage roads and to serve as recommended standards for track installation and maintenance. Fundamental features of haulage roads to permit high-speed, trouble-free transportation include: Good road bed, efficient drainage, proper alinement of tracks, economical grades, proper curvature on turnouts, well-ballasted ties of suitable size, good rails of adequate weight, good workmanship, and regular, systematic maintenance.

Roof Control

Progress continued in the introduction of roof bolting as a means of roof support in coal mines. A total of 758 mines was using bolts by June 30, 1954; 523 of them were active on that date.

35/ Kingery, D. S., Haulage Fatalities in Bituminous Coal Mines, 1953: Bureau of Mines HSS 425, Mineral Industry Surveys, 1954, 16 pp.

36/ Kingery, D. S., and Curry, T. F., Recommended Standards for Installation and Maintenance of Haulage Roads: Bureau of Mines Inf. Circ. 7701, 1954, 30 pp.

Significant progress has been made in the coal and iron-ore mines of Alabama in reducing the roof-fall fatality rates during the past several years by adopting systematic roof bolting.[37] The groundwork was laid through successful experiments early in 1948 by the Tennessee Coal & Iron Division of the United States Steel Corp. in cooperation with the Bureau of Mines. Since then, roof bolting has been adopted by various mines throughout the State. As of May 1953 roof bolts have been installed in 33 coal mines, 1 clay mine, and 14 iron-ore mines. Bolting has been done in all of the large coal mines, most of the medium-size coal mines, several small, hand-loading coal mines, and all iron-ore mines. Although there have been failures of bolted roof in most of the coal and iron mines, particularly when bolting was relatively new and experiments in roof bolting were being made, prevention of roof-fall accidents and increased tonnages generally obtained in roof-bolted areas are the chief benefits of roof bolting. Roof bolting not only reduces roof-fall accidents but also should be credited with preventing many other types of accidents that occur in various ways when timbering is used. Besides better roof support, benefits from roof bolting that do not show directly in statistics include better preparation of working faces, avoidance of accidental loosening or knocking out of timbers by blasting and moving equipment, more headroom in low coal, better ventilation without timber obstruction, better clearance in haulageways, and haulage and use of less bulky roof-control materials.

From a safety standpoint, widespread application of slotted-type bolts to control various types of mine roof has caused concern because the effectiveness of individual bolts in sustaining initial and additional roof loads could not be determined satisfactorily. An apparatus and procedure have been developed for testing the anchorage effectiveness of slotted-type bolts.[38] The apparatus consists of: (1) A hydraulic jack assembly for loading the bolt and (2) a device (extensometer or cathetometer) for measuring displacement of the bolt as it is loaded. This apparatus and procedure permit measurement of anchor slip for loads up to the yield load of the bolt. Two representative makes of slotted-type bolts (a total of 94 bolts) were tested in typical sandstone and shale mine roof. Analysis of the test results showed that: (1) Anchorage capacities up to the yield load of the bolts can be developed in either rock type; (2) the shape of the slotted end of the bolt affects the ease with which the bolt can be driven; (3) all bolts for which the driving distance was more than 1.25 inches produced satisfactory anchorage in both rock types (thus, driving distance can be used as a criterion for satisfactory anchorage); (4) for the group of bolts that was satisfactorily anchored the anchor slip was unaffected by the type of bolt but was considerably larger in shale than in sandstone; and (5) the bolt expansion that is, the amount the wedge expands the prongs in excess of the diameter of the hole can also be employed as a criterion for satisfactory anchorage. Although the bolt expansion and driving distance do not differ appreciably, the latter is recommended because it is easier to determine.

In an investigation of the torque-load relationship for 3/4-inch, expansion-type mine roof bolts, 24 combinations of 3/4-inch mine-roof bolts and expansion shell units were tested in each of 2 representative types of mine roof rock to establish the relationship between torque and bolt load and to determine the accuracy of measurement.[39] The relationship between torque and load was found to be 39.8 pounds bolt load per foot-pound of torque. This relationship is valid for torque up to 200 foot-pounds.

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[37] Young, H. C., Roof Bolting in Alabama Coal Mines and Iron-Ore Mines: Bureau of Mines Inf. Circ. 7678, 1954, 15 pp.

[38] Barry, A. J., Panek, L. A., and McCormick, J. A., Anchorage Testing of Mine-Roof Bolts. Part 1. Slotted-Type Bolts: Bureau of Mines Rept. of Investigations 5040, 1954, 12 pp.

Analysis of 117 occurrences of bumps in coal mines shows that 67.6 percent are associated with pillar-line points,[40] although slabbing and splitting pillars, development, and other unfavorable mining practices in abutment areas may be a contributory or the primary cause of bumps. To prevent pillar-line bumps it is necessary to recognize areas that can be expected to become highly stressed and to project the mining plan and operations to eliminate such areas insofar as possible. Coal and adjoining rock when subjected to a gradually increasing load usually adjust gradually by slow failure of the pillar or by slow flow of bottom or top shales. However, when the failure is sudden and explosive, a bump results.

Anthracite-Mine Flood Prevention

In seeking a solution of the anthracite mine-water problem the possibilities of preventing surface seepage by corrective measures at its source were explored.[41] In the Southern field it was found that 92 percent of the seepage into the mines is due to general surface infiltration and 8 percent is from stream beds. The possibility of applying remedial measures to minimize seepages was considered favorable. A similar study of barrier pillars in the different fields[42] covered 224 barrier pillars affecting 60 mines and confining 34 underground pools containing 21 billion gallons of water. Recovery of the coal from the pillars would largely depend on drainage of the pools.

Data were compiled on the volume and quality of the mine water handled by the pumping plants in the anthracite region and the pumping equipment utilized.[43] Mine-drainage systems in the anthracite region handle over 200 billion gallons of water annually, of which over 150 billion gallons is pumped to the surface. Existing drainage and pumping layouts are not adequate to cope with the increasing water problem. Comparison of costs of new tunnel or pumping installations involves variable operating factors. As a part of a comprehensive tunnel project, the proposed Conowingo tunnel system, project No. 1 (Lackawanna), has been proposed to serve the Northern field.[44]

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[39] Barry, A. J., Panek, L. A., and McCormick, J. A., Use of Torque Wrench to Determine Load in Roof Bolts, Part 2. Expansion-Type 3/4-Inch Bolts: Bureau of Mines Rept. of Investigations 5080, 1954, 17 pp.

[40] Holland, C. T., and Thomas, Edward, Coal Mine Bumps: Bureau of Mines Bull. 535, 1954, 37 pp.

[41] Ash, S. H., Link, H. B., and Romischer, W. M., Surface-Water Seepage Into Anthracite Mines in the Southern Field, Anthracite Region of Pennsylvania: Bureau of Mines Bull. 539, 1954, 52 pp.

[42] Ash, S. H., Barrier Pillars in Wyoming Basin, Northern Field, Anthracite Region of Pennsylvania: Bureau of Mines Bull. 538, 1954, 251 pp.

[43] Ash, S. H., Hower, C. S., Kennedy, D. O., and Lesser, W. H., Mine Pumping Plants, Anthracite Region of Pennsylvania: Bureau of Mines Bull. 531, 1953, 151 pp.

[44] Ash, S. H., Dierks, H. A., Kynor, H. D., Lesser, W. H., Miller, P. S., and Romischer, W. M., Flood Prevention in Anthracite Mines, Northern Field, Anthracite Region of Pennsylvania, Project No. 1 (Lackawanna): Bureau of Mines Bull. 545, 1954, 61 pp.

Coal-Mine Ventilation

Complete ventilation surveys by the absolute-pressure method were made in two coal mines, and partial surveys were made in two others in connection with coal-mine-inspection problems. A study was made in another coal mine to determine the effect of barometric pressure on methane emission from caved areas. Tests of an absolute-pressure water barometer were unfavorable, and further development of the instrument was postponed.

Economical solutions of problems of mine-ventilation improvement can be found by mathematical analyses of alternative methods of procedure; but, as regards older bituminous-coal mines, the airway network is usually so complex that mathematical solutions are too tedious to be practical. Recourse is usually made to extremely costly and uncertain trial-and-error procedures with the existing layout and equipment. The results often prove costly and sometimes create hazardous conditions. Both the economic and safety aspects of alternative methods of ventilation improvement may be rapidly and cheaply investigated with analogue computers. An electrical analogue computer, designed and built especially for analyzing mine-ventilation-distribution problems, has been placed in service by the Bureau of Mines at its Pittsburgh, Pa., Experiment Station. It is a nonlinear, low-voltage, fluid network analyzer of a type developed by Malcolm S. McIlroy, professor of electrical engineering at Cornell University.[45/] The Bureau unit has a capacity of 5 sources, 128 mains, and 48 loads.

The absolute accuracy of results when using the computer depends primarily on the accuracy of the data supplied for the analysis. All that is required to set up the analyzer for operation is the actual resistance values or relations of pressure to quantity for the component parts of the system. Actual pressure differences and quantity distribution can then be determined by analysis for any desired rate of total flow and any included regulated splits. Inaccuracies in original assumptions are eliminated in analyzer solutions as currents and pressures around loops are automatically balanced. Reported data for similar analyzers indicate that results within a maximum of 3 percent of calculated values may be obtained. Data for two complex networks for which field-survey data has been accurately balanced by mathematical methods were duplicated on the analyzer.

Mine Air and Dust

Under the Bureau of Mines program of coal-mine inspection, conducted under the provisions of the Federal Coal-Mine Safety Act, approximately 16,000 samples of mine air were analyzed to determine the adequacy of ventilation in coal mines, detect and aid in eliminating hazards from flammable and toxic gases in mines, provide information necessary in controlling and extinguishing fires in coal mines, and supply information in various other matters pertaining to health and safety in coal mining. Detailed information was published on the nature and occurrence of mine gases and mixtures of gases[46/] and on methods and equipment used in detecting them. Particular attention was given to flame safety lamps; methane-indicating instruments; various types of carbon monoxide detectors; methods for detecting atmospheres deficient in oxygen or containing accumulations of carbon dioxide; and methods for detecting hydrogen sulfide, oxides of nitrogen, and sulfur dioxide.

[45/] McElroy, G. E., A Network Analyzer for Solving Mine-Ventilation-Distribution Problems: Bureau of Mines Inf. Circ. 7704, 1954, 13 pp.

[46/] Forbes, J. J., and Grove, G. W., Mine Gases and Methods for Detecting Them: Bureau of Mines Miners' Circ. 33, revised, 1954, 82 pp.

A device has been developed and used to test for methane in difficult-to-reach places.[47] The equipment consists of a permissible flame safety lamp, rubber tubing, and an aspirator bulb. When fastened to a small nipple in the locking ring of the lamp to provide an air inlet, the other end of the tubing can be extended to the place from which the sample is to be taken.

Approximately 800 examinations were completed on samples relating to a study for the evaluation and control of dust hazards in the mining and mineral industries. These examinations included light-field and dark-field dust counts, X-ray diffraction, spectrographic and petrographic determinations, screen analyses, and determination of particle-size distribution. The samples consisted of a wide variety of materials, such as airborne dust, settled dust, coal, fly ash, drill cuttings, catalysts, slag, and various minerals.

Exposure of workers in the mining and mineral industries to the potentially harmful effects of airborne dust is a matter of concern in all countries where these industries exist. In recognition of the various problems involved in combating this hazard, matters pertaining to preventing and suppressing dust in mining, tunneling, and quarrying were discussed at a meeting of technical experts under the auspices of the International Labor Office in Geneva, Switzerland, December 1-17, 1952, when 88 technical papers were presented. Those participating represented Government agencies, management and labor, research, educational, and insurance organizations, all of whom were concerned with measures for protecting workers from harmful exposure to airborne dusts. Countries represented at the meeting were: Australia, Austria, Belgium, Canada, Chile, France, Germany, India, Italy, the Netherlands, Norway, Peru, Sweden, Switzerland, the Union of South Africa, the United Kingdom, and the United States. As a result of discussions at this meeting, certain recommendations pertaining to practices for preventing and suppressing dust in mining, tunneling, and quarrying were adopted and have been published by the Bureau of Mines.[48]

As part of a cooperative arrangement with the Signal Corps of the United States Army, the Bureau participated in a study of coal and coal ash as sources of certain rare elements. Spectrographic analyses were completed and results reported to the Signal Corps. Laboratory studies were begun to determine the number and size of coal dust particles in a cubic foot of air at the lower limit of an explosive mixture of the dust in air. Field surveys of dust conditions were made in response to requests at a coal-loading dock, in mines where continuous mining machines were in operation, and in connection with water infusion of pillars in coal mines. Approval testing of drill-dust collectors was continued, and new collectors were granted approval. One new approval and about 50 extensions of approvals for respiratory protective devices, including gas masks and dust respirators for personal protection in coal mines and other mineral industries, were issued. Work was continued on development of apparatus and techniques for testing respirators for use in connection with spray painting.

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[47] Davis, M. L., Testing for Methane in Out-of-Reach Places: Bureau of Mines Inf. Circ. 7703, 1954, 9 pp.

[48] Bureau of Mines, Recommendations on the Prevention and Suppression of Dust in Mining, Tunneling, and Quarrying. Adopted at a Meeting Held Under the Auspices of the International Labor Office, Geneva, Switzerland, December 1-17, 1952: Bureau of Mines Inf. Circ. 7677, 1954, 16 pp.

Testing Electrical Equipment

In the coal-mining industry the recurrence of disastrous mine explosions long ago pointed to the imperative need for proper safeguards in the use of electricity if such catastrophes were to be prevented. Present-day methods of mining, which involve concentration of a number of electrically driven machines at the working face, make it more necessary than ever that suitable precautions be taken to guard against electric sparks or flashes in explosive atmospheres.[49] The basic conditions that bring about a mine explosion initiated by electrical equipment improperly constructed or poorly maintained are: (1) Presence of gas in the immediate vicinity of the equipment; (2) penetration of the gas into the equipment by diffusion or other means; (3) ignition of the gas in the equipment by an electric spark or flash; and (4) failure of the equipment to prevent the spread of the flame resulting from that ignition.

Flashes from short circuits or grounds from trailing cables of portable machines may readily ignite gas. The trailing cable is, in fact, one of the major hazards in using electrical equipment at the face. Ignitions are also possible where short circuits or grounds occur on power and lighting circuits in the presence of gas. The main problem confronting the manufacturers of mine electrical equipment is to construct enclosures so that joints (and relief openings of protective devices, if used) will abstract enough heat from any flames tending to escape to cool them below the ignition temperature of methane, 650° C., and so that the enclosures will be strong enough not to burst when gas explodes in them. Flames may be cooled by contact with metallic surfaces at joints or discharge openings of protective devices through which they pass, from sudden expansion of the gases as they are released from the enclosure, or from both contact and expansion. Methods used by the Bureau of Mines in determining the safety of the design of equipment are outlined in Schedule 2E (Title 30, Sections 18.1 to 18.11, inclusive, of Code of Federal Regulations).[50] This schedule gives the procedure to be followed by manufacturers in submitting equipment for investigation, and it prescribes certain inspections and tests designed to disclose any unsafe features.

Owing to the size and weight of the equipment investigated, large apparatus is needed for effective testing. In this respect, the Bureau of Mines facilities for permissible testing of equipment in explosive atmospheres are believed to be the most complete of those of any country and the only ones of such magnitude in the United States. During the calendar year 1953, 95 enclosures were subjected to 2,683 explosion tests.

Several lists of permissible mine equipment tested and approved by the Bureau of Mines have been published. The present list,[51] complete to January 1, 1953, supersedes all previous ones. Schedules that have been revised are as follows: Schedule 2E (Procedure for Testing Junction Boxes and Electric-Motor Driven Mine Equipment for Permissibility); Schedule 6D (Permissible Electric Cap Lamps: Procedure in Testing, Fees Charged, and Requirements for Approval); Schedule 7C

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[49] Ilsley, L. C., Gleim, E. J., and Brunot, H. B., Inspection and Testing of Mine-Type Electrical Equipment for Permissibility; Bureau of Mines Inf. Circ. 7689, 1954, 23 pp.

[50] Gleim, E. J., United States Bureau of Mines Standard of Inspection and Test of Explosion-Proof Enclosures for Mining Equipment: Bureau of Mines Rept. of Investigations 5057, 1954, 7 pp.

[51] Brunot, H. B., Permissible Mine Equipment Approved to January 1, 1953: Bureau of Mines Bull. 543, 1954, 33 pp.

(Flame Safety Lamps: Requirements for Permissibility, Tests Made, and Fees Charges); Schedule 8C (Portable Methane Detectors: Requirements for Permissibility, Tests Made, and Fees Charged); Schedule 9B (Permissible Telephones and Signaling Devices: Requirements for Permissibility, Tests Made, and Fees Charged); Schedule 10C (Electric Mine Lamps, Other Than Cap Lamps: Requirements for Permissibility, Tests Made, and Fees Charged); Schedule 12D (Single-Shot Blasting Units); Schedule 16B (Procedure for Testing Multiple-Shot Blasting Units); Schedule 22 (Procedure for Testing Diesel Mine Locomotives for Permissibility and Recommendations on the Use of Diesel Locomotives Underground); and Schedule 24 (Procedure for Testing Mobile Diesel-Powered Equipment for Noncoal Mines). The present publication includes an appendix listing seven satisfactory fuels available for use in permissible flame safety lamps and shows where the fuels are available. This publication also includes an appendix listing manufacturers of flame-resistant trailing cables with the corresponding symbol that must be used by these manufacturers in marking trailing cables that have passed the test for flame resistance contained in Schedule 2E.

For many years mining men have sought a portable device that could be read directly and that would permit more accurate and positive detection of methane than is possible with flame safety lamps. A number of instruments providing this more positive detection and convenience have now been developed and approved.[52] Although these instruments have proved to be practical in coal-mine service, it is hoped that continued research and development of these instruments will result in improvements in accuracy and other features.

The Bureau of Mines, recognizing the need for establishing minimum requirements on which to base official approval of suitable methane-detection instruments, prepared Schedule 8. The present edition, known as Schedule 8C, was issued October 31, 1935, and provides for approval of two general classes of instruments or devices, namely, (1) detectors and (2) indicating detectors. With the first class, it is only necessary that the user be able to detect a minimum of 1 percent and a maximum of 3 percent methane in air. Flame safety lamps and methane alarms belong in this class. In the second class, the instrument or device must indicate as little as 0.25 percent methane in air. Although detectors having an upper-scale limit of 2 percent may be approved, it is recommended that they be designed to give indications up to 4 percent methane in air. The Bureau of Mines has thus far approved 12 methane detectors under the schedules issued.

PREPARATION AND STORAGE OF COAL

Coal Washing

Alaska

Washability examinations conducted at the Northwest Experiment Station contributed toward a decision by the Usibelli Coal Mine, Inc., of Alaska, to install a heavy-medium coal-washing plant at Healy Fork, Alaska with a capacity of 125 tons per hour. This plant, scheduled to begin operation in May 1955, will recover marketable coal from the thick dirty "G" bed (previously wasted) and will upgrade general production of this mine.

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[52] Gleim, E. J., Portable Methane-Detecting Appliances Approved Under United States Bureau of Mines Standard: Bureau of Mines Rept. of Investigations 5056, 1954, 6 pp.

Appraisal of Coal-Washing Results

At the Second International Coal-Preparation Congress, held in Essen, Germany, in 1954, the Bureau of Mines presented an appraisal of the results obtained in over 70 cleaning trials made on 12 coals in its Seattle dense-medium pilot plant. The most important conclusion reached was that the distribution curve of the pilot plant - which is a plot showing the proportions in which each density fraction of the feed was recovered in the washed coal or rejected in the refuse - is substantially independent of either the density composition of the feed or the density at which the plant is operated.[53] Because of this characteristic the curve can be used to predict very accurately the results to be expected in treating any particular coal in the plant. It is believed that distribution curves representing commercial cleaning equipment can be used in the same manner, thus constituting a valuable tool in forecasting the results to be expected in a projected cleaning operation.

The data from these cleaning trials, as well as those representing several commercial dense-medium operations, were used to judge the reliability of various criteria employed in evaluating washery performance. The criterion "probable error," which is the slope of the distribution curve in the intermediate-density range, in some cases failed completely to distinguish between three conditions: (1) A good separation, (2) one in which the recovery of clean coal was incomplete, or (3) one in which the rejection of impurity was incomplete. This failure occurs because probable error is determined solely by the treatment afforded material of intermediate density, ignoring completely the recovery of the lighter coal and rejection of heavy impurity. Since the material of intermediate density often comprises only a few percent of the feed, the probable error is not considered reliable.

The criterion "error area," which is the area bounded by the distribution curve and the lines representing a perfect separation, proved much more reliable in distinguishing between good and bad cleaning performance. Error area takes into account how the entire feed is separated and therefore is not subject to the limitations of probable error.

Cleaning and Dewatering Fine Sizes of Bituminous Coal

One of the most difficult problems in coal preparation is the cleaning and dewatering of the very fine sizes. Because of the fineness of the particles these sizes cannot be treated satisfactorily by processes that depend on specific gravities and hindered settling ratios.

Froth flotation is suggested as one means of solving the fine-coal-cleaning problem. The Elmore vacuum process of flotation has been used to some extent in England but has received little attention or study in this country. An investigation has therefore been made to obtain data and information on this process under laboratory conditions.[54] During this investigation an effort was made to evaluate the relative efficiencies of vacuum and mechanical laboratory froth-flotation cells, using parallel tests on 2 samples of 14-mesh to 0 raw coal and 1 sample of slurry from the overflow from a settling tank. In general, the results with the mechanical cell were superior to the ones with the vacuum cell with respect to both the individual sizes and the composite of all sizes in the flotation feed.

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[53] Yancey, H. F., and Geer, M. R., Some Practical Aspects of Appraising Coal-Washing Results: Contrib. C-10, 2d Internat. Coal-Preparation Congress, Essen, Germany, 1954, pp. 1-8.

[54] Riley, H. L., and Gandrud, B. W., Laboratory Evaluation of Vacuum Flotation for Cleaning of Coal Fines: Bureau of Mines Rept. of Investigations 5071, 1954, 33 pp.

Another possible method for cleaning fine coal is by using the feldspar jig. Feldspar jigging refers to the practice, derived from ore concentration, of using a false bed of heavy material on the screenplate of the jig to limit the flow of material through the screen. No refuse gate is provided above the screen, all refuse being removed through the artificial bed into the hutch compartment. Feldspar jigs were employed in American washeries many years ago, but gradually were supplanted by other types of equipment. In continental Europe, however, the feldspar jig has continued to be the principal device for cleaning fine coal. The jig has undergone continuous improvement in design, and the modern feldspar jig may well have application to current American coal-preparation problems. Its principal appeal is a much higher capacity per unit of space than equipment generally used here.

European coal-preparation practice differs so much from our own that it is impossible to translate European results directly in terms of possible American application. For this reason an experimental study of the feldspar jig has been initiated at the Northwest Experiment Station of the Bureau of Mines, Seattle, Wash.55/ As a preliminary step to obtain design information, the jig shown in figure 14 was built. It is a piston jig having a washing compartment 1 foot square and a capacity of 1/2 to 1 ton per hour when treating 1/4-inch to 0 coal. The results obtained thus far are encouraging. A coal of unusual washing difficulty because of its bony character and fineness was treated by this method and yielded a clean product containing 11.3 percent ash from a feed analyzing 17.7 percent with a recovery efficiency of 98.9 percent. The sharpness of the separation effected between coal and impurity decreased markedly in the sizes finer than 48-mesh, owing to incomplete rejection of impurity. The investigation is being continued to show how the effectiveness of the feldspar jig compares with that of the wet table and to provide information on capacity.

Dense-Medium Pilot-Plant Tests

An investigation of washing performance of the Bureau of Mines laboratory cone-type pilot plant for coal preparation at Bruceton, Pa., has been completed. Data comparing the use of pulverized refuse with magnetite for preparing dense mediums are to be published. Test results indicate that use of pulverized refuse for dense-medium processes would be limited to cleaning coarse sizes and low to moderate specific gravities. Mediums comprising this material become very viscous above 1.45 specific gravity. Higher recovery efficiencies and sharper separations were obtained with magnetite medium. Sharper separations were especially evident on sizes below one-half inch, which the magnetite medium separated more efficiently. For sizes above 1 inch, the pulverized-refuse medium compared favorably with magnetite medium.

An investigation of recovery of coal from coal-mine refuse piles is completed, and the results are to be published. The recovery of coal from mine refuse in a crescent-type dense-medium washery employing pulverized mine rock at a feed rate of 175 tons per hour was studied. Two types of mine refuse were tested: Freshly mined and that which had been mined 2 years previously and piled on a waste dump. Washing

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55/ Yancey, H. F., Geer, M. R., and Custred, U. K., The Feldspar Jig for Cleaning Fine Coal: Coal-Mine Modernization, Am. Min. Cong., 1954, pp. 233-239.

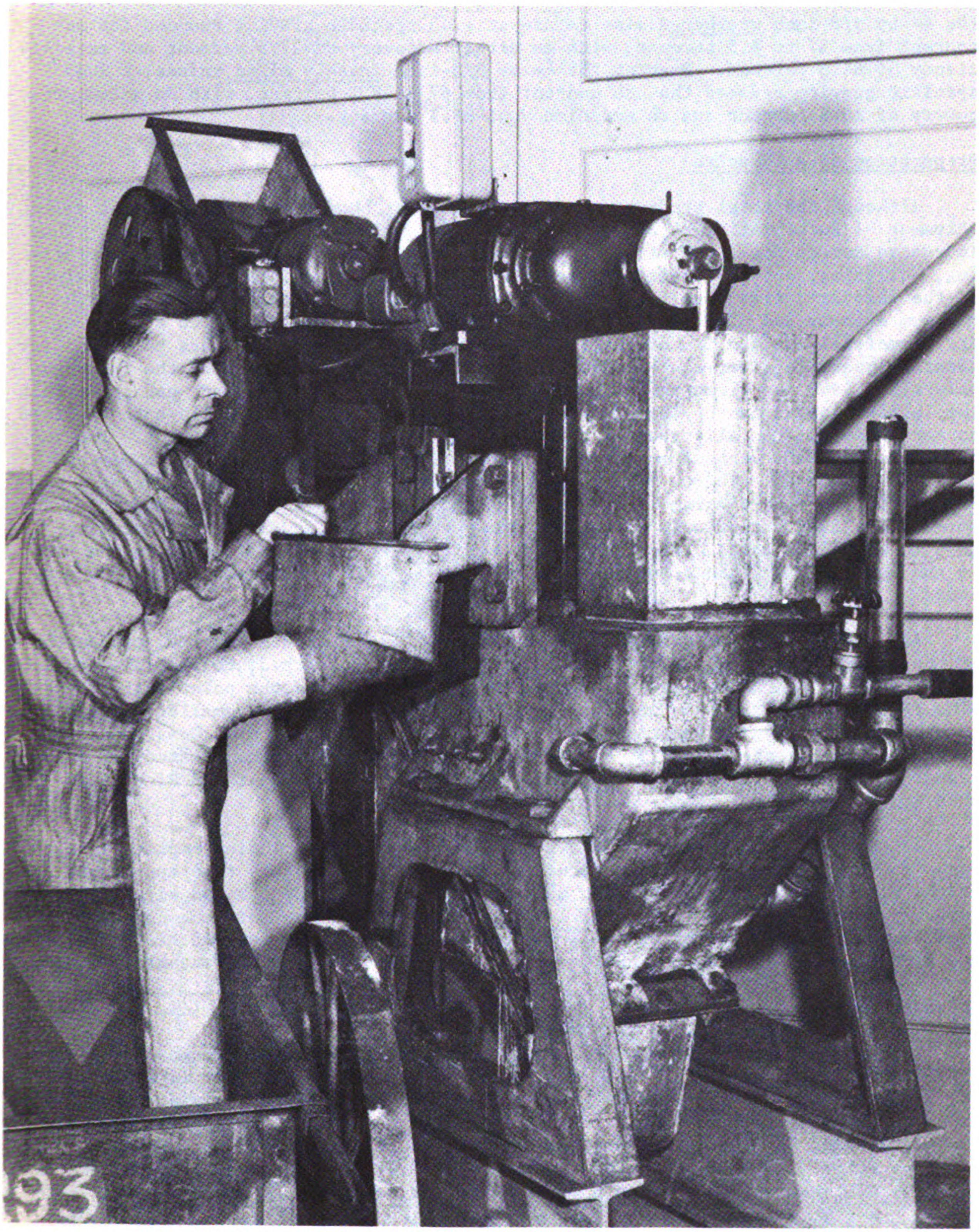

Figure 14. - Small feldspar jig for cleaning fine coal, Bureau of Mines, Seattle, Wash.

the 4- by 3/8-inch weathered mine refuse at 1.45 specific gravity reduced the ash content from 57 to 8.5 percent, with an actual recovery of 27.5 percent and an efficiency of 86.8 percent. Washing the 4- by 3/8-inch freshly mined refuse at 1.45 specific gravity reduced the ash content from 67 to 8.1 percent, with an actual recovery of 20.8 percent and an efficiency of 89.3 percent.

Preparation of Anthracite

Although the total production of anthracite has been declining in recent years, shipment of Buckwheat No. 4 and smaller anthracite sizes has been increasing. This increased demand for finer sizes of anthracite has created new problems in the sizing, screening, and desliming of fine anthracite. The relatively low dollar value of the recovered fine coal requires that preparation practices be conducted with maximum economy and efficiency. To that end, the Bureau has completed a study of the commercial application of the launder screen,[56] a device that has been used for about 50 years in river-coal-dredging operations but has been used by the industry only since 1949 for cleaning prepared sizes of anthracite. The study has shown that the launder screen can be used to prepare efficiently and economically both the feed to and products from all types of anthracite fine-coal-cleaning equipment. The device is stationary with no moving parts and is simple in construction, as may be noted in figure 15. Thirty fine-coal-cleaning plants now use launder screens. Figure 16 is a flow diagram of one anthracite fine-coal-cleaning plant where launder screens are used exclusively to reclaim Buckwheat-No. 5-size anthracite formerly lost in the plant waste. From solids of the size and ash consist shown in the feed to the screens, marketable Buckwheat No. 5 is recovered at the rate of 12 tons per hour.

Anthracite-crushing practices previously were predicated on maximum production of the larger sizes (Egg, Stove, and Chestnut) by using toothed, double-roll crushers. Consumer demand for these larger sizes has declined to the point where a surplus is now being produced, whereas shortages often exist in the smaller sizes, particularly in the Buckwheat and Rice range (9/16- by 3/16-inch). Consequently, at the request of the industry, the Bureau of Mines has undertaken a study of size-reduction methods that will yield maximum production of Buckwheat and Rice sizes when crushing the larger size coals.

A number of nonroll-type crushers have been studied, including impact, jaw, ring, and gyratory types. Of the crushers studied, the gyratory type appears to be the most efficient in recovering maximum quantities of the desired sizes. The gyratory crusher shown in figure 17 is rated at 17 to 22 tons-per-hour capacity when crushing dry limestone and will produce approximately 62 percent of Buckwheat and Rice sizes at 21 tons-per-hour capacity when grinding Chestnut anthracite.

Preparation of Lignite

Tests of power requirements for lignite pulverizing were conducted on a bowl-type pulverizing unit at the W. J. Neal Station, Central Power Electric Cooperative, Voltaire, N. Dak. In these tests gross power input to the motor driving the pulverizer and exhauster fan was found to vary from 23.5 kw. per hr. per ton at the lowest tested loading, 35 percent of rated capacity, to 16.4 kw. per hr. per ton at the rated capacity of 20,000 pounds of lignite per hour. Net power consumption, determined by subtracting the no-load power requirement, was approximately constant at

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[56] Sanner, W. S., and Clendenin, J. D., Anthracite Launder Screens: Factors in Their Design and Operation: Bureau of Mines Rept. of Investigations 5032, 1954, 32 pp.

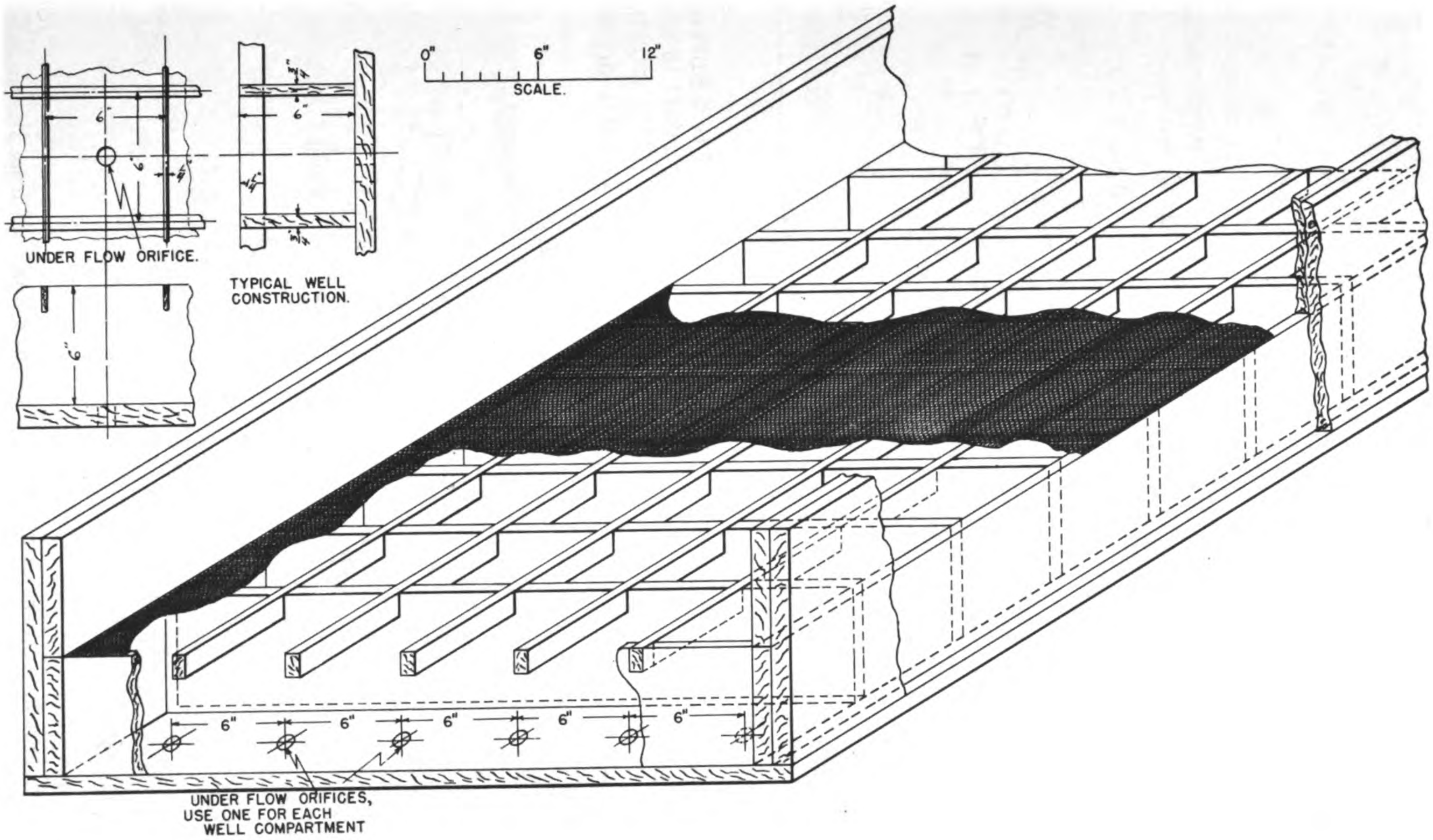
0"
6"
12"
SCALE.
6"
6"
1/4"
UNDER FLOW ORIFICE.
6"
3/4"
6"
1/4"
3/4"
TYPICAL WELL CONSTRUCTION.
6"
6"
6"
6"
6"
6"
UNDER FLOW ORIFICES, USE ONE FOR EACH WELL COMPARTMENT

Figure 15. - Construction of launder screen for recovering fine-size anthracite.

Original from THE OHIO STATE UNIVERSITY

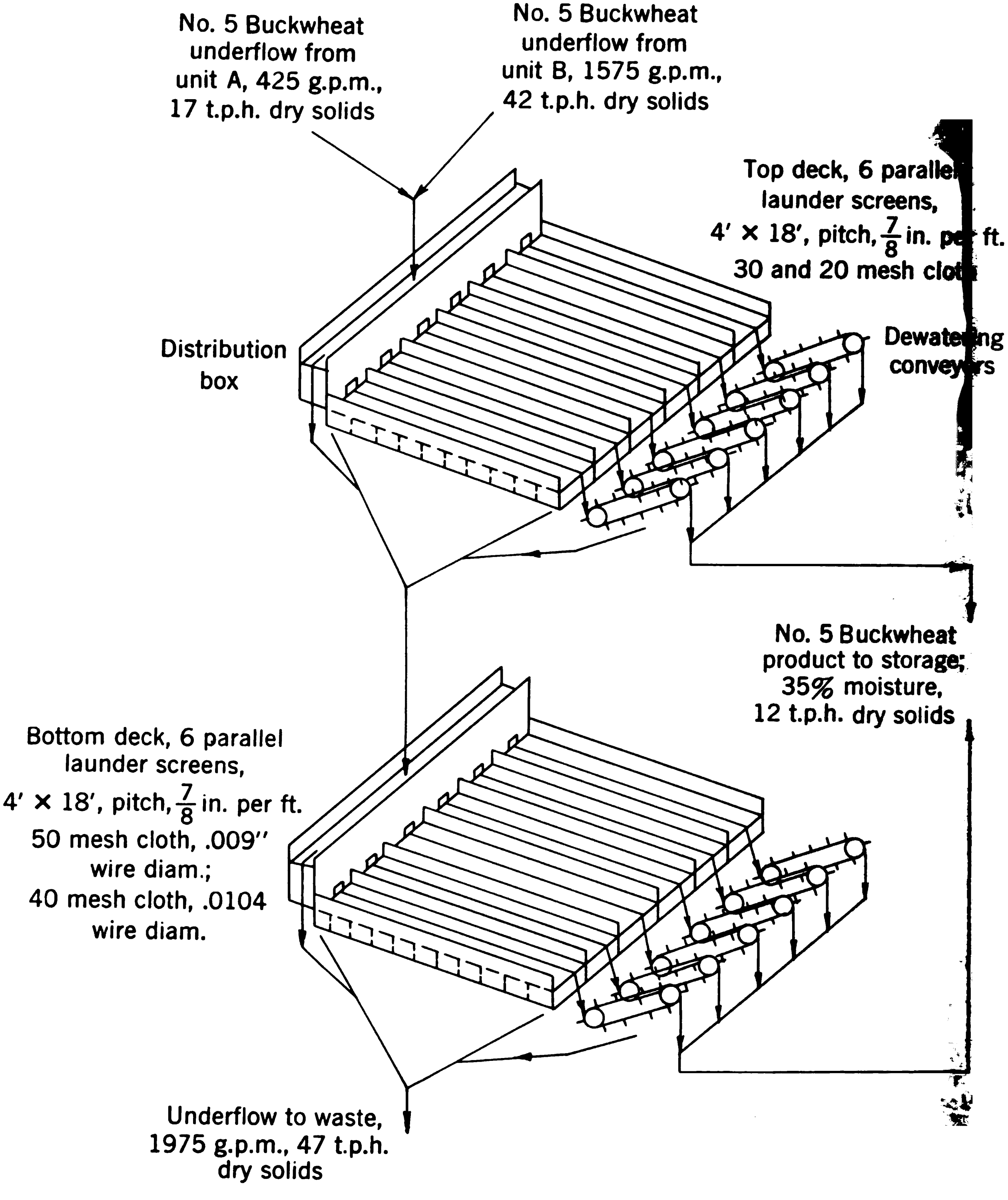
No. 5 Buckwheat underflow from unit A, 425 g.p.m., 17 t.p.h. dry solids
No. 5 Buckwheat underflow from unit B, 1575 g.p.m., 42 t.p.h. dry solids
Top deck, 6 paralle launder screens, 4' × 18', pitch, $\frac{7}{8}$ in. p ft. 30 and 20 mesh clo
Distribution box
Dewate ng conve rs
No. 5 Buckwheat product to storage; 35% moisture, 12 t.p.h. dry solids
Bottom deck, 6 parallel launder screens, 4' × 18', pitch, $\frac{7}{8}$ in. per ft. 50 mesh cloth, .009" wire diam.; 40 mesh cloth, .0104 wire diam.
Underflow to waste, 1975 g.p.m., 47 t.p.h. dry solids

Figure 16. - Anthracite launder-screen installation, recovering fine coal from plant-waste slurry.

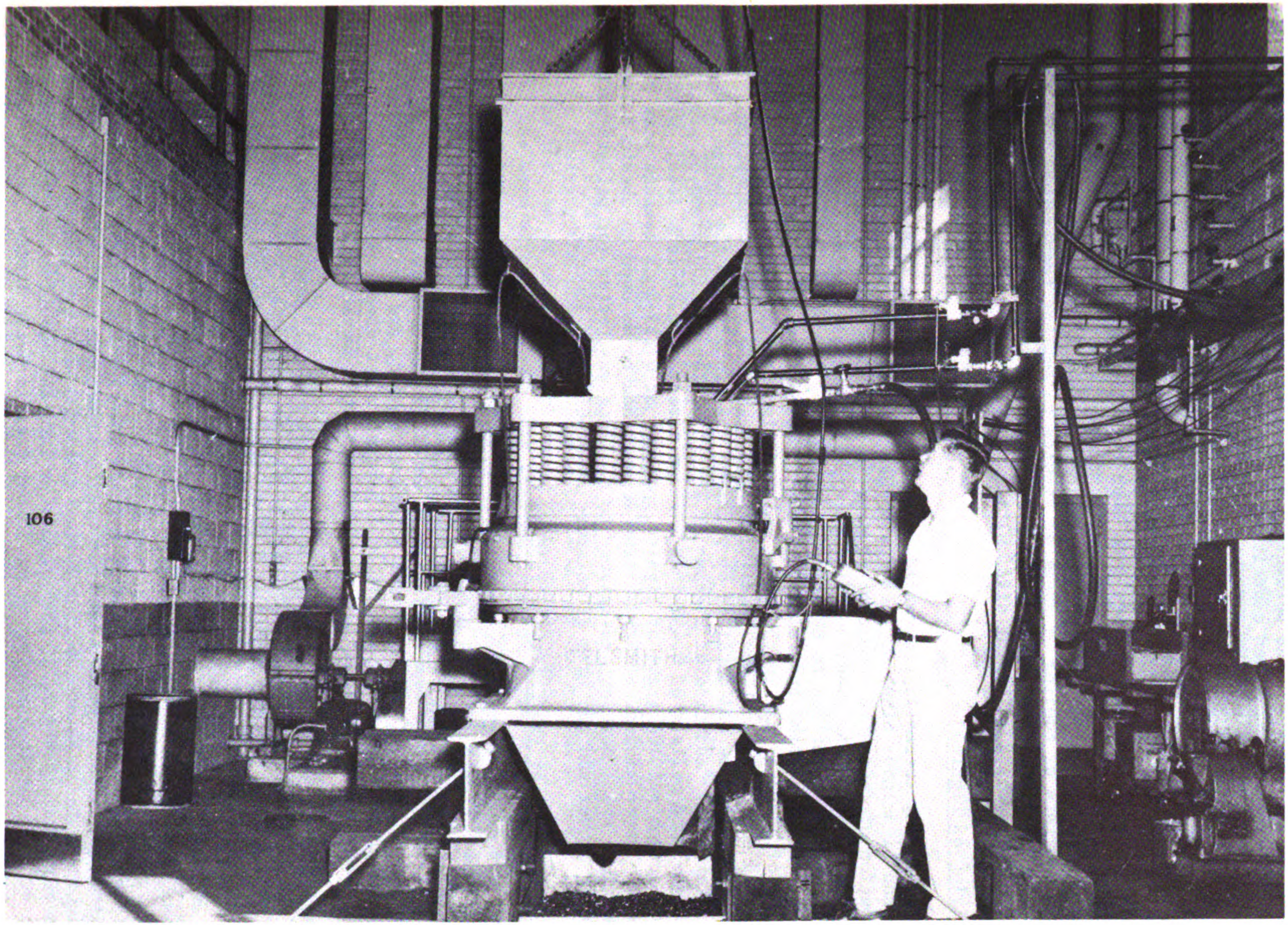

Figure 17. - Gyratory crusher and loading hopper, Anthracite Research Laboratory, Schuylkill Haven, Pa.

11.1 kw. per hr. per ton. The percentage of pulverized product passing 200-mesh was lowest (52.1 percent) at rated capacity and maximum (78.5 percent) at the normally operated loading of 75 percent. Preheated primary air at 575° to 625° F. is introduced into the mill to partly dry the lignite as it is being pulverized and to transport it to the burners. The moisture content of the pulverized product ranged from 15.1 percent at the 35-percent test loading to 27.8 percent at rated capacity.

Preliminary observations have been made to determine factors that influence freezing of lignite in cars and to develop methods to minimize it. Factors that have been found to influence degree of agglomeration are: Time in transit, size consist, and rate of cooling of as-mined lignite to ambient temperature. In North Dakota oil treatment, applied at the rate of 3 to 4 quarts per ton, has been found effective in reducing unloading difficulties.

Pelletizing of Lignite

Pelletizing thermally pretreated small-size lignite was investigated with starch and bituminous binders. Results showed that average particle size and size distribution of feed were important factors in effecting agglomeration with minimum binder consumption. An excess of fine particles increased binder consumption because of the large surface to be coated. Generally, larger pellets were obtained at longer residence time and relatively low rotational speed of the pelletizing drum. Reduction of contact time in the mixer between lignite particles and binder before charging to the pelletizer was beneficial with regard to binder consumption. The shortest contact time was obtained by spraying the binder onto the charge fed to the pelletizing drum. Addition of 5 grams of starch binder per 100 grams of pretreated lignite produced pellets of 0.498-inch average size from 0.15-inch feed. With 1.25 grams of starch per 100 grams of lignite, pellets of 0.213-inch average size were obtained. Larger amounts of briquetting asphalt had to be used to obtain a product of comparable size; however, resistance to handling was better for pellets made with bituminous binder and the rate of moisture absorption was lower.

Drying of Lignite by the Fleissner Process

The influence of steam pressures up to 1,500 p.s.i. and the effect of quick application and release of steam pressure on steam-drying characteristics of North Dakota lignite were investigated on a small pilot-plant scale. At the highest operating pressure, moisture removed as liquid water during heating and steaming periods constituted 58.3 percent of the total moisture removed, and the final moisture content of the dried lignite was less than 1 percent. Net steam consumption at 1,500 p.s.i. pressure was 0.83 pound per pound of moisture removed.

Size degradation during drying was not consequential; however, bloating of particles at 1,000 to 1,500 p.s.i. contributed to low bulk density and reduced strength of the product. At 1,500 p.s.i., 22.5 cubic feet of gas, containing 97 percent carbon dioxide, was formed per 100 pounds of lignite as charged.

Storage of Low-Rank Coals

The seasonal demand for coal in the Western States during the winter season is three times greater than in the summer months. Most of the coal is mined as ordered. Very little off-season storage has been practiced because of the danger of spontaneous ignition in piles of low-rank coal. Acceptance and application of proved storage techniques would level the production rate and should reduce fuel costs. Storage will be particularly important in the Pacific Coast States, since several million tons of Rocky Mountain low-rank fuel probably will be used annually in that area for power production.

The development of safe storage methods has been studied for several years by the Bureau of Mines. Many techniques were investigated including pit storage, capped piles, and uncapped surface storage.[57] Spontaneous ignition can occur in piles of stored coal when air is free to circulate through the mass. Safe storage requires restriction of this air flow by careful placement of the coal to avoid segregation and by thorough compaction. Uncapped surface piles were found to be the most practical means of storing large quantities of coal. This method entails placing the coal in lifts about 1 foot in depth with each increment compacted to break up air channels and to reduce void space. Sides are maintained with a maximum slope of about 14° to minimize segregation of the sizes and to facilitate thorough compaction of the sides. The final surface is smoothed to reduce wind effect.

Subsurface pit storage is satisfactory where pits are available. The rules for subsurface storage are the same as for surface storage, except that the pile will have straight walls conforming to the sides of the pit.

Capped piles covered by asphalt emulsion, earth, or cinders were tested but were not considered as satisfactory. Such piles provide safe storage as long as the cap remains intact. When breaks occur in the cap from erosion, settling, or shrinkage, air moves into or out of the pile, resulting in fires. Capped piles can be serviced to keep them safe, but the maintenance costs may be excessive.

The techniques of removing coal from storage piles are as important as those of pile formation. In general, the coal should be removed from the surface of the pile and the newly exposed surface smoothed and compacted. Steep sidewalls must be avoided when only a portion of a pile is reclaimed.

Preparation Characteristics of Coking Coal

In 1950 a program was initiated to supplement the coking-coal-reserve investigations by studying the preparation characteristics of United States coals that can be upgraded for use as metallurgical fuel. This investigation, which is reported by counties, has been extended during this reporting period to include 2 counties in West Virginia and 1 in Tennessee. The most difficult washing problem is usually reduction of sulfur. In addition to the counties listed below, for which publications have been released, studies of preparation characteristics of coking coals are in progress on coals from other counties in West Virginia, Kentucky, Pennsylvania, and Tennessee.

Putnam County, Tenn.

The Wilder (Bon Air No. 2) bed is the only coal bed of minable thickness in Putnam County, and reserves in this bed are relatively small.[58] Present production is used for domestic and industrial heating and power generation. Sulfur content of this coal ranged from 4.5 to 5.6 percent and ash content from 14.0 to 14.4 percent. It was found that even fine crushing and mechanical cleaning would not yield a cleaned coal chemically suitable for metallurgical use under present standards.

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[57] Allen, R. R., and Parry, V. F., Storage of Low-Rank Coals: Bureau of Mines Rept. of Investigations 5034, 1954, 31 pp.

[58] Williams, L., Lowe, R., Turnbull, L. A., Carman, E. P., Crentz, W. L., Reynolds, D. A. and Abernethy, R. F., Estimate of Known Recoverable Reserves and the Preparation and Carbonizing Properties of Coking Coal in Putnam County, Tenn.: Bureau of Mines Rept. of Investigations 5029, 1954, 21 pp.

Raleigh County, W. Va.

Raleigh County contains large reserves of high-quality, high-, medium-, and low-volatile coals generally low in sulfur and ash or readily upgraded by reducing the sulfur and ash content enough to make them suitable for metallurgical use.[59] The premium coking coals in the county are the Pocahontas No. 3, Pocahontas No. 4, and Fire Creek. Production is expected to increase from the principal beds, which are: Eagle, Powelton, No. 5 Block, Hernshaw, Fire Creek, and Pocahontas No. 6. Reduction of sulfur was only moderately difficult in 1 sample collected from the Upper Eagle bed containing 2.1 percent sulfur and 11.1 percent ash. Some difficulty was experienced in reducing the sulfur content of a sample taken from a high-sulfur area of the No. 2 Gas bed to below 1.45 percent. Samples from the top bench of the Eagle bed showed areas of relatively low sulfur and of high sulfur content. Crushing, coupled with precise washing was necessary to reduce sulfur below 1.25 percent. With 1 sample collected from the Peerless bed it was also difficult to reduce the sulfur below 1.25 percent and so upgrade it to metallurgical fuel.

McDowell County, W. Va.

McDowell County contains large reserves of low-ash, low-sulfur, low-volatile coal, most of which is suitable for metallurgical fuel.[60] The principal and higher quality reserves are found in the Pocahontas No. 3, Pocahontas No. 4, Pocahontas No. 5, Pocahontas No. 6, Beckley, and Sewell beds. These coals are suitable for metallurgical use in the run-of-mine state or can be readily upgraded by simple preparation. The Pocahontas No. 9, Fire Creek, Little Raleigh, and Welch beds generally must be upgraded by mechanical cleaning to be suitable for metallurgical use. Metallurgical-grade coal can also be produced from the medium-volatile Iaeger and Douglas beds by washing. The Eagle bed is a high-volatile coal having medium ash and low sulfur content and can be readily upgraded to meet present metallurgical standards.

UTILIZATION OF COAL AND OTHER FUELS FOR COMBUSTION

Trends in Energy Demand in the Western States

The most significant trend in the fuel picture for the 11 Western States since 1900 has been the supplanting of coal by oil and natural gas.[61] In 1900 coal supplied 75 percent of the total energy requirements, oil about 6 percent, and hydropower about 19 percent. By 1952 only 8 percent of the total energy requirements was supplied by coal, 15 percent by hydropower, 19 percent by natural gas, and 58 percent by oil. The drop in the coal figure reflects the loss of much of the domestic heating market to gas and oil, the loss of a substantial portion of power generation (particularly in the Pacific Coast States), and the tremendous use of petroleum products for mobile power.

59/ Miller, J. W., Jolley, T. R., and Sokaski, M., Preparation Characteristics of Coal From Raleigh County, W. Va.: Bureau of Mines Rept. of Investigations 5070, 1954, 32 pp.

60/ Miller, J. W., Jolley, T. R., and Sokaski, M., Preparation Characteristics of Coal From McDowell County, W. Va.: Bureau of Mines Rept. of Investigations 5094, 1954, 41 pp.

61/ Parry, V. F., and Landers, W. S., Trends in the Demand for Energy in the Western States, 1900-75: Proc. 49th regular meeting, Rocky Mountain Coal Mining Inst., 1953, pp. 47-56.

Generation of thermal electric power appears to be the chief market that coal can recapture. The annual demand for electric power in the Western States is at present about 80 billion kw.-hr. It is estimated that requirements of these States will reach 260 billion kw.-hr. by 1975. This increase reflects both the increase in population and the increased power consumption per capita. At present coal is producing less than 5 percent of the power, oil 13 percent, gas 13 percent, and hydroelectric installations 71 percent. It is anticipated that hydropower will increase and supply 130 billion kw.-hr. by 1975, or about 50 percent of the total power generated. The remaining power will be generated by thermal power plants fired by coal, gas, and oil. The controlling factors in selecting fuels for powerplant use are the delivered cost of heat and the permanence of supply. The supply of all fuels will probably be high for the next 25 years, and the selection of fuel for power production will depend primarily on the cost of heat. The trends indicate that both natural gas and oil will go to domestic and small industrial heating, chemical production, and specialized use. These uses can command a higher price than power plants can afford to pay, and the bulk of the thermal power will probably be generated from coal after the cost of heat from coal becomes less than the cost of heat from the competing fuels. These trends are being anticipated at present by utility companies, several of which are providing space for coal-burning facilities in their new central-station installations. By 1975 coal is expected to supply 117 billion kw.-hr. per year and oil and natural gas about 6 billion kw.-hr. each. The changeover to coal from natural gas and oil is expected to be gradual at first and then to accelerate as the differential in cost per heat unit becomes greater. If the above trends materialize, coal production in the Western States should increase from the present approximately 22-million-ton rate to about 92 million tons in 1975, 54 million tons being used for power generation and 38 million tons for domestic and industrial use.

Fuel-Engineering Service

Consulting and field-testing services were continued by the Bureau of Mines to aid Federal agencies in selecting, testing, and using fuel and fuel-burning equipment. At the request of the various departments as listed, the following services were rendered. For the United States Department of Justice, recommendations were prepared (based on previous test work) that resulted in a reduction of $7,500 in the contract price for a new powerplant at the Federal Penitentiary, Leavenworth, Kans. For the General Services Administration, equipment and operation at the Pentagon boiler plant, Washington, D. C., was surveyed, resulting in recommended changes to improve operating efficiency. For the Federal Supply Service, tests were made of the operating characteristics of a number of coals delivered for trial at various plants in the Washington, D. C., area. The results of these tests were used in determining awards for contracts for large tonnages of coal.

A study for the United States Department of the Air Force resulted in recommendations against the use of refuse oil from aircraft maintenance for fuel in the central heating plant at Brookley Air Force Base, Ala. Tests of automatic controls and combustion safeguards at the new boiler plant of the Bureau of Mines Appalachian Experiment Station, Morgantown, W. Va., provided information for the final acceptance of the boiler and firing equipment. For the Veterans Administration, field tests were made of a revamped stoker and furnace in a new hospital boiler plant at Pittsburgh, Pa., which provided technical data for a decision on the type of fuel to be used during summer operation of this plant. The new Capitol boiler plant in Washington, D. C., was tested for contract requirements and to show the effects of load and cinder reinjection on efficiency. Results of these tests are used to plan operation for best efficiency.

For the United States Post Office Department, an inspection trip was made with its chief engineer to study fuel-burning equipment at two large post offices in New York City; mistakes in installation were determined and changes made in operation to overcome serious difficulties that were destroying the boilers. Services on 111 other special problems were given 29 different Federal agencies.

At the request of the Maryland Health Department, several of its personnel were trained to judge stack-smoke density using the Ringelmann chart. A study was made of a new instrument for determining smoke density from stacks, comparing observations with this instrument and those made using the conventional Ringelmann chart. A report covering this study is being prepared for publication.

Ignition and Combustion in Fuel Beds

To extend the studies of fuel beds beyond the scope of underfeed and overfeed types, the Bureau of Mines investigated the third basic type of fuel bed - crossfeed ignition and burning.[62] Crossfeed ignition is characterized by the ignition plane moving perpendicular to the direction of flow of the air. The test furnace used in this investigation is shown in figure 18.

The variation of the rate of ignition travel with air-mass-flow rate was studied for the following solid fuels: A subbituminous B and a high-volatile A bituminous coal, an anthracite, and a high-temperature coke. The results of this investigation showed that:

1. Pure crossfeed ignition does not usually occur in actual operation in fuel beds on traveling grates. On this-type grate ignition is by the underfeed principle under most normal operating conditions.

2. The rates of ignition in pure crossfeed beds are much lower than underfeed-ignition rates at comparable primary air rates, but high ignition rates are attained at air rates higher than are possible with stable underfeed beds.

3. Evolution of tars, vapors, and soot, which mask the radiation effect in the ignition zone with some fuels, and the development of a plastic layer with coking coals explains, at least in part, the low rates of ignition of such highly reactive coals as subbituminous B and high-volatile A coals compared with high-temperature coke of relatively low reactivity.

4. Chemical reactivity in its conventional concept apparently bears no relation to the rates of travel of ignition through the beds; this conclusion applies to both underfeed and pure crossfeed ignition.

5. Up to the present, there have been no known applications of pure crossfeed ignition and burning in fuel beds, except for a small anthracite stoker. The present investigation has indicated that the pure crossfeed principle could be applied in commercial processes for special purposes. One of these possibilities is the combustion of low-grade fuels, such as washery refuse, to produce lightweight aggregates.

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[62] Graf, E. G., Carman, E. P., and Corey, R. C., Pure Crossfeed Ignition in Fuel Beds: Combustion, vol. 26, No. 3, September 1954, pp. 59-66.

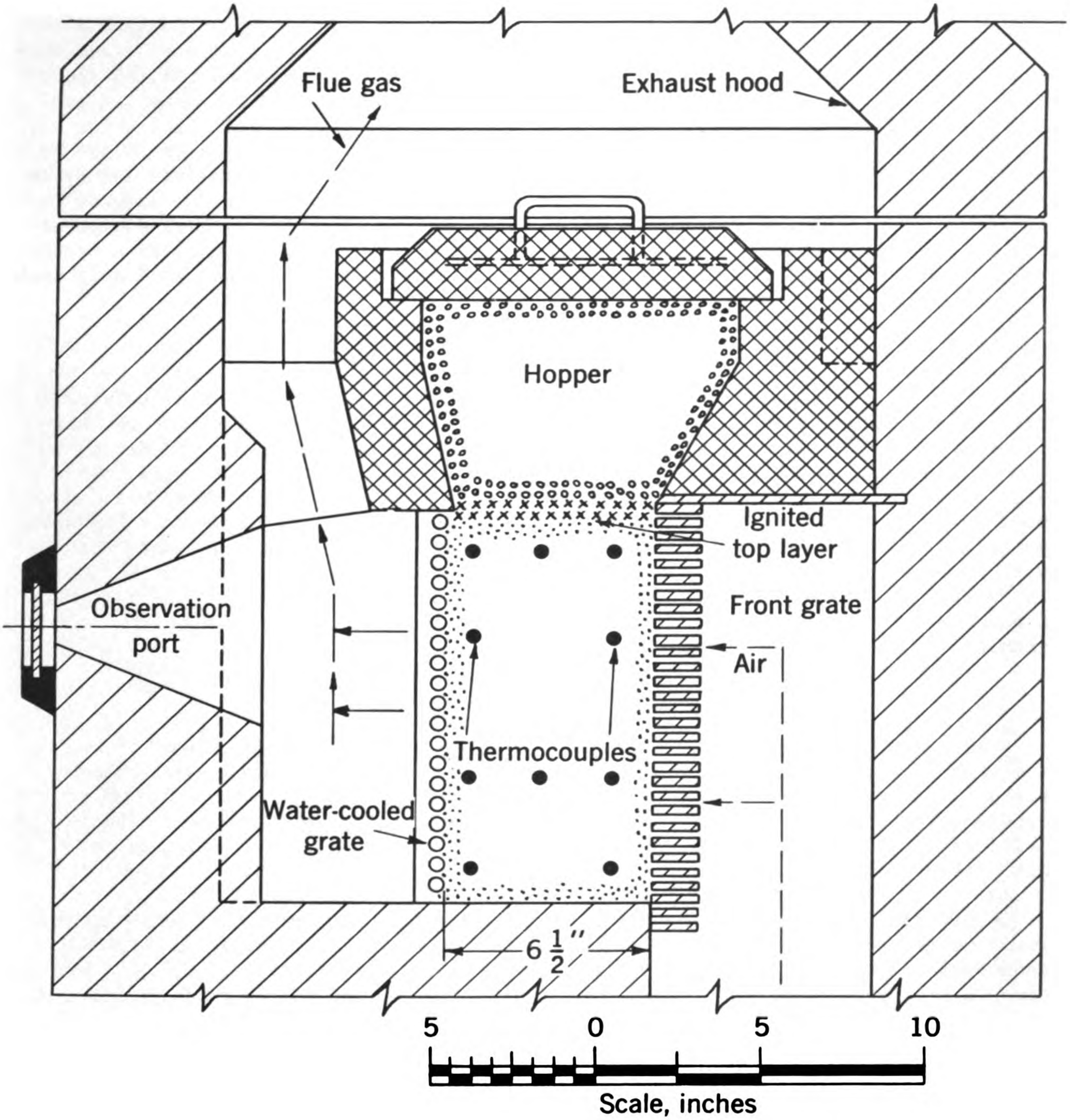

Figure 18. - Cross section of test furnace used in crossfeed investigation.

Combustion of Anthracite for Agricultural Purposes

At the request of anthracite-industry representatives a technical and economic study was made of the use of anthracite in portable heaters for controlling frost damage to farm crops and in portable crop driers. A report is in process of publication on the frost-control study, indicating that market potentialities for anthracite appear to range from less than 100,000 tons to possibly as much as 250,000 tons annually under severe weather conditions. In the crop-drier study it was found that existing anthracite stoker and furnace equipment can be adapted to this use. On the basis of this study, one manufacturer of this type of equipment built a portable stoker-fired crop drier to use Rice-size anthracite. As a result of favorable tests with the trial unit, he is planning to manufacture and sell such driers.

Disposal of Radioactive Wastes by Incineration

Because the disposal of the radioactive solid wastes of hospitals, universities, and small commercial projects is becoming a more severe problem as the utilization of radioactive isotopes becomes more widespread, the Bureau of Mines, in cooperation with the United States Atomic Energy Commission, has designed, constructed, and tested a low-capacity institutional incinerator. Figure 19 is a photograph of the unit. The results of performance tests with sawdust as the waste material indicated that the optimum operating conditions for this unit are obtained with 35-pound charges and at an air rate of approximately 55 cu. ft. per minute. The burning rate was about 50 pounds per hour. A publication on this work is not planned because the nature of the cooperative agreement did not provide for a complete study of variables.

Tests of Army Stoves and Cookers

In continuing the study of the performance of Army heating equipment, under a cooperative agreement with the Office of the Quartermaster General, performance tests with three fuels, leaded gasoline, kerosine, and fuel oil, were run on an experimental Bunker heater. Rated output of 20,000 B.t.u. per hour was readily obtained with leaded gasoline, but output dropped to 74 percent of that value with kerosine and to 59 percent with fuel oil.

Endurance tests of this heater were also conducted, using leaded gasoline and fuel oil as fuels. Prolonged operation with leaded gasoline at high fuel-flow rates caused deterioration of some component parts. Oxidation and scaling induced by high temperatures continued to increase until, after 600 hours of operation, burnthrough resulted. When fuel oil is used frequent cleaning is essential to prevent the buildup of carbon deposits. These carbon formations interfere with proper operation of the antiflooding device in the unit and increase the smoking tendency of the heater by reducing the supply of air available for combustion.

A new type of immersion heater was tested for performance with leaded gasoline as fuel. Drafts, carbon dioxide concentration in the stack gas, and stack-gas temperatures were higher than those obtained in the Standard G. I. immersion heater. Smoothness of burning, lack of puffing, and a decreased smoking tendency even at high fuel-flow rates were noted. However, the thermal efficiencies were much lower than those of the standard unit.

A standard test procedure was established to permit evaluation of the relative efficiency of spark arresters under similar conditions. Six different designs of spark arresters were built and tested for performance.

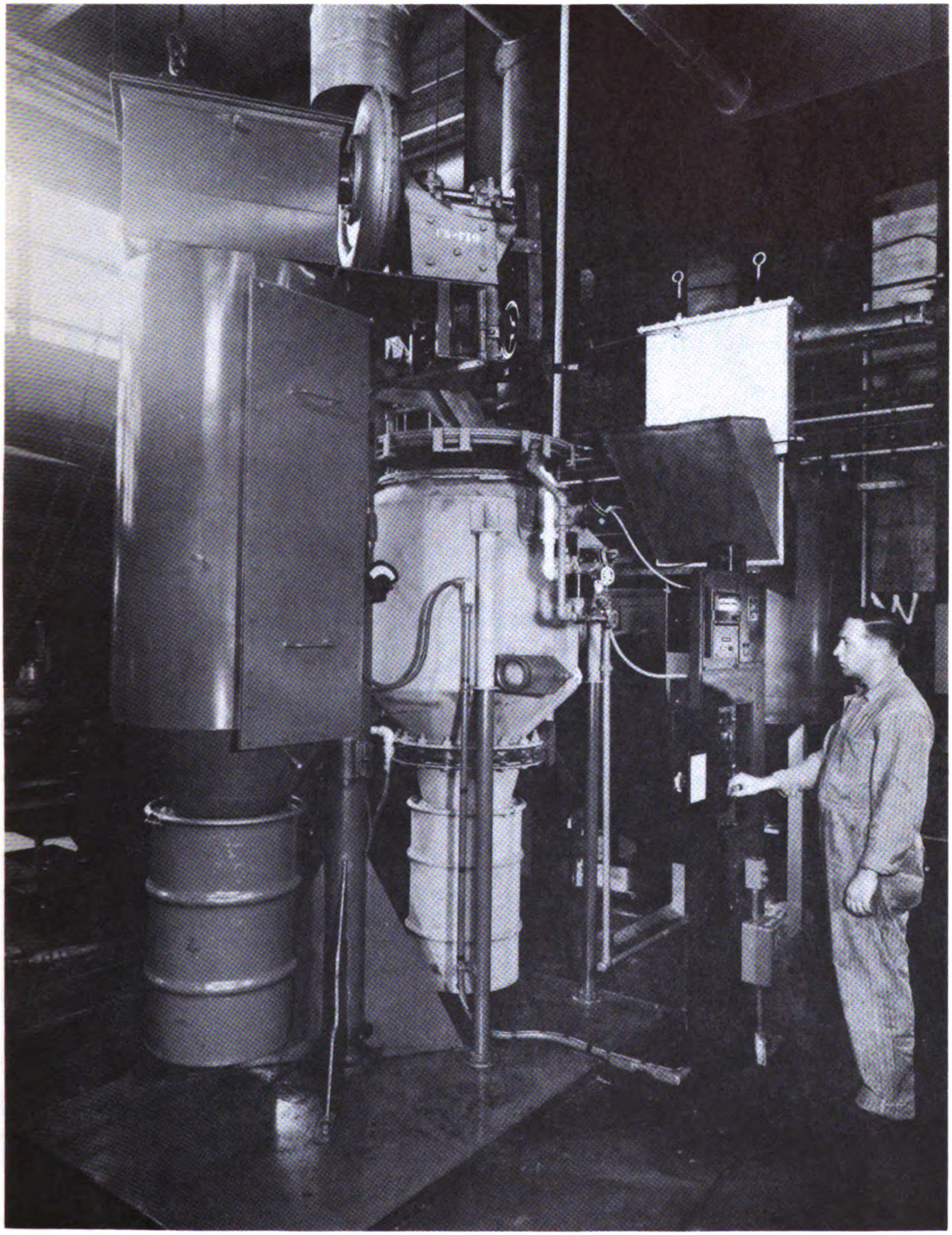

Figure 19. - Institutional incinerator for disposal of radioactive combustible wastes.

Special reports that give the detailed results of this work have been submitted to the Office of the Quartermaster General.

Tests of Fuel-Oil Additives

Work was continued on the usefulness of proprietary additives employed in many Federal heating plants for improving the utilization of No. 6 fuel oil. The phase dealing with the effectiveness of such additives on sludge formation and accumulation in fuel-oil storage tanks was completed, and a report of investigations is currently being processed to make the results available to plant operators. The second phase deals with the effectiveness of the additives in controlling the tendency for soot deposits to form on the heat-exchange surfaces in the flue-gas passages. Preliminary efforts were directed toward establishing a controlled set of operating conditions for the laboratory furnace, so as to set up a standard sooting procedure. The effectiveness of additives is compared in terms of the relative quantities of soot formed under standardized conditions.

OTHER INVESTIGATIONS RELATED TO FUEL UTILIZATION

Utilization of Washery Refuse

The Bureau of Mines, in cooperation with the Truax-Traer Coal Co., conducted an investigation to determine the feasibility of burning refuse from washeries and preparation plants on a chain-grate stoker to make lightweight aggregate for concrete. Fundamental data were obtained from small-scale tests on the effect of such variables as size consist of the refuse, primary air rates, and furnace wall temperatures. The data from these tests were applied in designing a 10-sq. ft. chain-grate stoker and in developing the proper operating procedure. The results of tests run in this unit led to the following conclusions:

1. Aggregate satisfactory in density, size consist, and combustible content can be prepared by burning washery refuse on a chain grate. Aggregate being discharged from the 10-sq. ft. traveling grate is shown in figure 20.

2. The combustion chamber of the furnace should be designed to retain as much heat as possible in the ignition zone to assist in igniting the fresh feed. A flue-gas exit at the feed end is necessary to meet this requirement.

3. The refuse should be crushed and pelleted to obtain a size distribution satisfactory for burning. Pelleted refuse containing 10 to 12 percent moisture may be burned satisfactorily.

The results of the investigation were used as the basis for designing a pilot plant for the Truax-Traer Coal Co. to produce 60 to 75 tons of aggregate per day.

Recovery of Trace Elements From Anthracite Ash

Some anthracite ashes have been found to contain significant quantities of germanium and other trace elements. At the request of the anthracite industry, fly-ash samples have been collected from 11 boiler installations in powerplants burning anthracite on traveling chain stokers or in pulverized-fuel burners. These, with samples of the raw coals being fired at the time of sampling, are being analyzed to determine whether further work is justified.

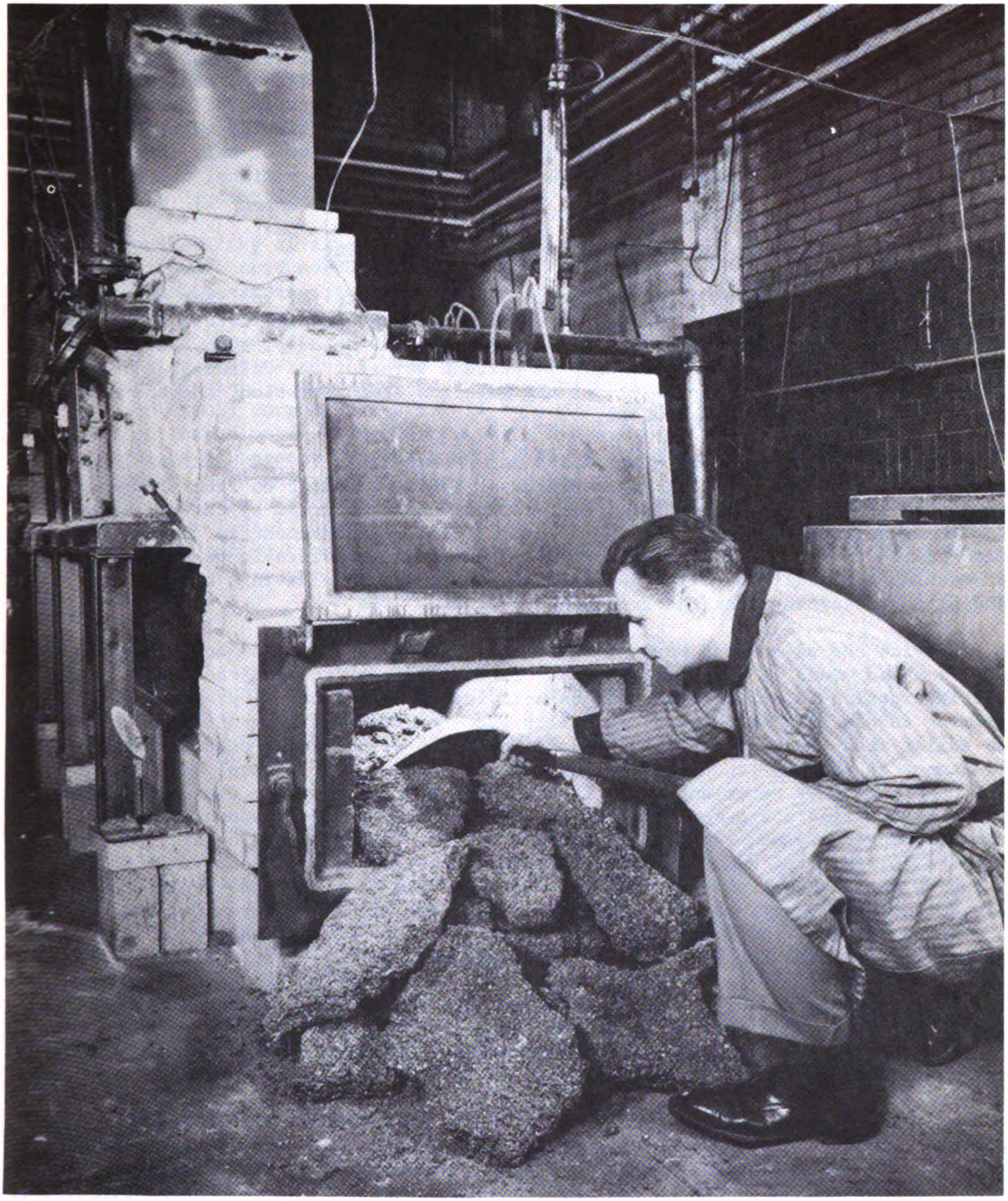

Figure 20. - Aggregate being discharged from the 10-sq. ft. traveling grate.

Flow Properties of Fine Powders

In cooperation with the Army Chemical Corps, an investigation was conducted on pneumatic transportation of fine powders, such as pulverized coal, and the major factors influencing the energy requirements and ease of operation of pneumatic systems were delineated. In conjunction with this work, a continuing survey of current developments in fluid dynamics has been maintained. A review of this literature was published as part of the annual Unit Operations Review of a national chemical journal.63/

Boiler-Feed-Water Conditioning

An increase of about 4 percent over 1953 in the total of analyses and resulting recommendations made on samples of boiler water and raw and return water samples submitted by Federal agencies in 1954 brought the total of such analyses to 12,739 for the year. Of these, about 74 percent were for the United States Department of Defense, about 16 percent for the Veterans Administration, and the remainder for 11 other Federal agencies.

In all, 1,086 Bureau of Mines field water-test kits, 17,928 bottles of chemical reagents, and 25,486 test kit replacement parts were sent to Federal agencies in 1954. Since simple order forms sent directly to the Bureau by the boiler-plant engineers were used to order these materials, with reimbursement to the Bureau made centrally by the various departments, substantial savings in purchase-order processing were believed effected, in addition to the main savings to equipment and piping resulting from the treatment program.

Advice and assistance were given several Federal agencies on boiler-water problems and means of alleviating them. These services included recommendations and instruction in determining the conductivity of boiler water; prevention of priming in new boilers; control of boiler water causticity; prevention of corrosion in boiler-feed lines and in standby boilers, water systems, and steam generators; treatment to prevent recurrence of scale and sludge and for control of chemical residues in boiler water and water in hot-water heating systems; use of Bureau of Mines return-line corrosion testers; control of clogging of blowdown lines; and use of proprietary compounds and gadgets for boiler-water conditioning. In addition to four Federal heating plants in the District of Columbia and vicinity, agencies benefiting from these services included the United States Departments of Air Force, Navy, Justice, and Post Office; the Veterans Administration; the Bureau of Indian Affairs; the Coast Guard; the National Park Service; the Public Housing Administration; the Public Health Service; and the National Institutes of Health.

A representative of the Department of Mines and Technical Surveys of Canada, Industrial Water Section, was given information on the operation and organization of the Boiler-Water Service as a guide for a similar service to be set up by the Canadian Government.

A 6-State questionnaire survey of 472 post-office boiler plants using boiler-water treatment recommended by this Bureau was made by the United States Post Office Department. This group was chosen as a sample of about 3,000 post-office plants in the treatment program. Of the 440 replies received, 81 percent indicated improvement in internal boiler conditions since beginning of treatment and expressed satisfaction with results; 17 percent indicated no apparent change. It is believed that, in this last group of plants, a large number do not need to pretreat the water used in their boilers. Only 6 plants - 1.3 percent - reported unsatisfactory results.

63/ Weintraub, M., Fluid Dynamics: Ind. Eng. Chem., vol. 46, No. 1, January 1954, pp. 112-117.

In these cases excessive blowdown appeared to be the main difficulty. The total number of boilers now being serviced is estimated to be 9,300. Since savings of $3,400 per year in maintenance and replacement costs are reported by some representative plants, it is obvious that total savings to the Government through this service are very substantial.

Boiler-Water Research

Corrosion in Condensate

The probability of expensive replacement of condensate return-line piping, owing to carbonic acid corrosion, continues to be a source of anxiety to Federal heating-plant operators. A total of 204 Bureau of Mines condensate return-line testers have been installed in such plants to furnish a quick and reliable evaluation of the probable rate of pipe deterioration. Chemical treatment, shown to be effective in laboratory tests, has been applied in plants where corrosion was found to be a potential hazard, and the results of such treatment have been evaluated by additional corrosion tests. In this manner, valuable field data are being compiled on the effectiveness of preventive treatment and on costs under the various conditions of operation. These data tend to show that general use of preventive treatment as an insurance against corrosion is now impractical because the treatment chemicals are relatively expensive. On the other hand, in special instances such as installations in Alaska, where replacement of buried pipe is very difficult, preventive treatment is obviously desirable; operating such installations to reduce raw-water makeup tends to limit treatment costs to less than $1.00 per million pounds of steam generated.

Laboratory testing was concerned primarily with the effect of preventive treatment on metals other than iron, inasmuch as such metals as brass, bronze, and copper are frequently found in condensate lines. Also, it was necessary to determine to what extent undertreatment of the system would induce deterioration at rates even higher than those experienced with no treatment at all.

Gadgets

Operators of Federal heating plants have been increasingly besieged by salesmen of various appliances and gadgets described as removing the need for boiler-feed-water treatment. Scale and corrosion are said to be prevented through magnetic, electrical, or other affects on the water. Inasmuch as the practical man in the plant frequently wonders if the salesmen may be right and the experts could be missing some new truth not yet fully appreciated, considerable trouble was taken to provide cooperating agencies with information on the more aggressive promotions. In one instance, a properly conducted trial of an induced-electric-field device led to condemnation of the use of a small boiler in a local plant after a 15-week run. In a discussion of a paper presented at a national water conference,64/ some aspects of the sale and use of gadgets for boiler feed-water conditioning were presented.

Oil in Boiler Water

A new $1,500,000 boiler and turbine plant for the United States Justice Department had been tied into old steam mains. Very large phosphate deposits in these mains were found to contain approximately 10 percent oil, and the new boilers had

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64/ Berk, A. A., Discussion on Gadgets for Practical Performance in Water Conditioning: Proc. Eng. Soc. Western Pennsylvania, 14th Ann. Water Conference, 1953, p. 164.

become fouled with this oil. After the boilers were cleaned with a special detergent formula that included sodium metasilicate and a polyphosphate and the system washed piecemeal with polyphosphate and detergent, the deposits giving rise to the trouble were removed quickly and completely, and the plant was operated at peak load without difficulty.

When the University of Maryland heating plant, which supplies steam to the Eastern Experiment Station, began to distribute oil-charged steam, the source of the oil was located in the secondary oil heater. Since only the one boiler was available, emergency measures were taken to remove the oil with minimum interruption of service. The bulk of the oil was floated from the upper drum by loading the boiler with a foaming detergent. Approximately 100 gallons of oil was removed in 2 hours. The boiler was then operated under reduced load until several locomotive boilers were brought in to supply steam while a more thorough cleaning job was done.

Analysis of Water-Formed Deposits

The composition of deposits formed in a boiler or its auxiliaries frequently can be interpreted to provide a guide for practical preventive or corrective treatment to avert operating trouble and costly shutdowns. In most instances, complete and detailed information is required to show how to avoid the recurrence of failure, and unless the information is accurate it can be most misleading. Accordingly, tried and tested methods are desirable for the chemical analysis of such deposits. Procedures have been selected that provide accurate results in a reasonable time with equipment available in most laboratories.65/ A diagrammatic outline provides for eliminating unnecessary steps when a complete analysis is not required or when some of the components included in the overall scheme are not present. Alternate procedures are given when use of special, unusual apparatus provides outstanding savings in time.

A Symposium on Boiler Water Chemistry was arranged for the American Chemical Society's Division of Water, Sewage, and Sanitation. The introduction to the symposium66/ emphasized that, although the chemist in powerplant work is primarily an analyst, he is of little value to his management unless his interests extend beyond his workbench and he is a full member of the operating team. Analyses of plant waters and water-formed deposits are required only to check on quality or correct trouble. Accuracy is frequently needed for sound interpretation of findings, but a variety of determinations must also be made as quickly as possible. By using comprehensive schemes, including selected procedures for chemical analysis, the work of the chemist can be organized and planned to provide the background essential for proper diagnosis and correction.

Boiler-Water Chemical Engineering

A panel discussion on What's New in Boiler-Water Chemistry was organized and moderated for the American Chemical Society. In the introductory remarks67/ the purpose was stated to be the presentation of the omnibus report on recent developments in the field of boiler-water chemical engineering. A panel of six experts summarized newer literature and unpublished information on chemical cleaning of boilers; preparation of boiler feed water; treatment to prevent corrosion, encrustation, and carryover; and chemical treatment to prevent corrosion by condensed steam.

65/ Neat, F. U., and Berk, A. A., Analysis of Water-Formed Deposits: Ind. Eng. Chem., vol. 46, No. 5, May 1954, pp. 961-970.

66/ Berk, A. A., Boiler-Water Chemistry: Ind. Eng. Chem., vol. 46, No. 5, May 1954, p. 953.

67/ Berk, A. A., and Partridge, E. P., Panel Discussion - What's New in Boiler-Water Chemistry: Ind. Eng. Chem., vol. 46, No. 5, May 1954, p. 983.

The evolution of the modern steam generator has been made possible by a partnership to which chemical engineers contribute important new skills in water conditioning. It is an indication of this evolution that embrittlement cracking of boiler seams, rather recently an important topic of panel discussions, can now be covered briefly as a minor aspect of boiler corrosion that the chemical engineer has learned to control. The emphasis now is on economy of operation through clean boilers and clean turbines; the preservation of the expensive boiler and its auxiliaries from corrosion, fouling and overheating; and the dependable availability of the steam-generating and steam-utilizing plant.

Air and Stream Pollution

Smoke Abatement

Smoke-abatement work throughout the United States continued to be very active. Cities requesting Bureau of Mines publications and consulting service included: New Westminster, B. C., Los Angeles, Calif., Bartow, Fla., Chicago, Ill., Everett, Mass., Detroit and Trenton, Mich., Buffalo and Sodus, N. Y., Lorain, New Philadelphia, and Zanesville, Ohio, Philadelphia, Pa., and Providence, R. I. At the request of Maryland, a smoke law applicable to the State and to its cities was suggested.

Air Pollution

Interest in air pollution by the Bureau of Mines extends back to its establishment in 1910.68/ Early investigations embraced studies of the smoke problems of boiler plants and those involving obnoxious and toxic gases and vapors from metallurgical plants and other sources. Since this time the Bureau has pioneered in developing and testing methods and instruments for detecting, sampling, and measuring pollutants in the atmosphere. Investigations have included work on gases and vapors, such as benzene, carbon dioxide, carbon monoxide, hydrocyanic acid gas, hydrogen sulfide, mercury vapor, methane, petroleum vapors, and sulfur dioxide.

Mounting concern throughout the world, as well as in the United States, about air pollution was instrumental in bringing about the assembling and publication by the Bureau of a comprehensive annotated bibliography containing over 4,000 references on air pollution.69/ References cited discuss all aspects of the problem including its nature and origin, prevention, control, and cost.

Data obtained from technical literature and by direct inquiry to all State governments as to their regulations on the maximum allowable limits of various air pollutants from the standpoint of health, damage to vegetation and property, and requirements of industrial processes were also published by the Bureau.70/ Work on air-pollution difficulties at the International boundaryline between Canada and the United States in the vicinity of the Detroit River was continued for the International Joint Commission by its Technical Advisory Board on Air Pollution, which includes a representative of the Bureau of Mines as one of its four United States members. The work of this board is resulting in a considerable reduction in smoke from vessels plying the Detroit River.

68/ Barkley, J. F., Air Pollution Work of the Federal Bureau of Mines: APCA News, vol. 2, No. 5, July 1954, pp. 1-3 and 5.

69/ Davenport, S. J., and Morgis, G. G., Air Pollution, a Bibliography: Bureau of Mines Bull. 537, 1954, 448 pp.

70/ Barkley, J. F., Accepted Limit Values of Air Pollutants: Bureau of Mines Inf. Circ. 7682, 1954, 6 pp.

Stream Pollution

Cooperation was continued with the New England-New York Interagency Committee for its publication, The Resources of the New England-New York Region. Part II of this publication is composed of 39 chapters, and each chapter is being issued as a separate "Gold Book." Of these 39 Gold Books, 27 have already been reviewed. In addition to these Gold Books, 10 pollution-control reports on river drainage basins throughout the United States, issued by the United States Public Health Service, were reviewed.

As a part of the New England-New York Interagency Survey of waterborne mineral wastes, chemical engineers inspected 519 industrial plants. These inspections resulted in surveys of 364 plants discharging consequential flows of waterborne wastes of mineral origin to the streams of New York and the New England States. A report is being prepared on the data procured in the completed surveys of 665 plants taken since September 1952.

A pilot-size liquid-solid cyclone was used in plant studies to show how valuable sand fines may be salvages from wasted wash waters discharged from the washing of sand and gravel. A comparative study was made of the operation of a commercial-size sand drag and a commercial-size clarifier used for the same purpose. Further operation of the cyclone will produce enough data for publication and show the relative merits of sand drags, clarifiers, and the liquid-solid cyclones for processing waste water laden with suspended solids. Production of salable products will increase, and stream pollution will be abated when industry projects these plant studies into full-scale operation.

Diesel-locomotive repair and service at two yards of a large railway system caused serious stream-pollution problems because of the discharge of waste waters to the local streams. A program of good housekeeping and control of the discharge of the waste waters was prepared for the yards and is now being put into effect. When the program is completed, enough data will be available for a publication useful to other railroads facing similar problems.

A large steel mill was causing serious stream pollution because of the discharge of waste waters with a high palm-oil content. Research by the Bureau showed how flotation of the waste water would remove the palm oil as a sludge from the water. A full-scale plant was erected by the steel mill and is now operating satisfactorily. After further treatment of the sludge, the palm oil is being removed and reused. Not only was the stream pollution abated, but there was a net saving of $200,000 a year on costs of purchasing new palm oil. A report covering this work, which may be applied to all steel mills that discharge waste palm oil, has been written and is to be published.

COAL CARBONIZATION

Analysis of Coking-Industry Accident Data

A statistical report on deaths and injuries in the coking industry for 1951 indicated marked progress in the reduction of injuries to employees as compared with 1950.[71] The fatality rate (0.14) per million man-hours of exposure declined 33 percent and was the second best performance since statistics were first collected on the industry in 1916. The non-fatal-injury rate (10.94) declined 8 percent and was the best since 1940. The industry employed 25,715 men, and of the total number of injuries resulting from accidents during the year, 10 were fatal, 25 resulted in permanent disability, and 743 caused temporary disability. Accidents resulting in the largest number of injuries were burns, falls of persons, handling materials, haulage equipment, use of hand tools, and falling objects.

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[71] Reese, S. T., Kearney, N. W., and Miller, E. A., Injury Experience in the Coking Industry, 1951: Bureau of Mines Bull. 527, 1954, 26 pp.

Survey of Carbonizing Properties of American Coals

In 1928, in cooperation with the American Gas Association, the Bureau of Mines initiated a study of the carbonizing properties of American coals. A pilot-scale metal-retort carbonizer was developed, along with a recovery train, to determine yields of coke tars, coal chemicals, and gas. This system, the Bureau of Mines - American Gas Association (BM-AGA) apparatus, has been used to determine carbonizing properties and yields of several hundred American and foreign coals, and tests in a pilot-scale sole-flue expansion oven have yielded data on expanding properties of coking coals. The results of this continuing investigation have provided industry with a ready reference on the carbonizing properties of coals and blends, in which increased interest has been shown as reserves of many of the better coking coals have diminished. A complex index of the coals studied, giving in brief tabular form the data from these and related investigations, has been published.[72] Listings of the coals tested are given by States, beds, and mines, with a bibliography containing references to more detailed published information, where available.

In 1954 the survey of the carbonizing properties of American coals by the BM-AGA method has been continued, with tests at a carbonizing temperature of 900° C. Emphasis was placed on evaluating coals for suitability for use in manufacturing metallurgical coke. The yields of carbonization products were also determined. Expansion tests in the sole-heated oven were made on most samples containing 65 percent or more fixed carbon on the dry, mineral-matter-free basis.

During the year 42 coals from 28 beds in the Appalachian region were carbonized singly. These samples represent important beds in Butler, Indiana, Greene, and Mercer Counties, Pa.; Harlan, Letcher, Pike, and Perry Counties, Ky.; Mingo County, W. Va.; Claiborne County, Tenn.; and Buchanan County, Va. In addition to these, 1 Indiana coal, 1 Utah coal, and blends of 6 low-volatile Somerset County, Pa., coals and 1 McDowell County, W. Va., coal with Pittsburgh-bed coal from Washington County, Pa., were tested. A study, including blending tests, was made of the carbonizing properties of 4 Colombia, South America, coals and 4 Philippine Island coals to determine their suitability for metallurgical use. Since unpublished data on the carbonizing properties and yields of carbonization products will be published later, only a brief discussion by States, counties, and countries is included in this report.

Pennsylvania Coals

Armstrong County. - Although 7 coal beds in this county contain minable reserves, only coals from the Upper Freeport, Lower Kittanning, and Lower Freeport beds were considered for coking tests for a county report.[73] because reserves in the other 4 beds are limited. Carbonizing properties of 6 samples of Upper Freeport and 2 samples of Lower Kittanning coal were determined. The Lower Freeport coal was not tested because of its rather spotty occurrence and lack of operating mines from which samples might be obtained. Both the Upper Freeport and Lower Kittanning coals were found to yield cokes meeting present strength requirements for high-volatile blending coals for metallurgical purposes. The shatter indexes and ash content of coke made from Upper Freeport and Lower Kittanning coals are higher, but stability and hardness indexes are normal compared with 20 high-volatile A bituminous blending coals that have been used for making metallurgical coke. Although, the sulfur content of the cleaned Upper Freeport coal is within the range considered acceptable for high-volatile blending coal, sulfur content of the Lower Kittanning coals is higher than is acceptable.

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[72] Brown, R. L., Davis, J. D., Reynolds, D. A., and Smith, F. W., Carbonizing Properties of American Coals; Index of Coals Tested by the Bureau of Mines: Bureau of Mines Bull. 536, 1954, 17 pp.

[73] Smith, F. W., Wolfson, D. E., Reynolds, D. A., Naugle, B. W., Birge, G. W., Carbonizing Properties of Armstrong County, Pa., Coals: Bureau of Mines Rept. of Investigations 5101, 1954, 20 pp.

This report is the first in a series giving carbonizing properties of coals, by counties, as the third phase of the Bureau of Mines investigation of coking-coal reserves and supplements the reports on known recoverable reserves and on preparation characteristics of American coking coals.

Butler County. - Eight coals from the Upper and Lower Freeport, Upper and Lower Kittanning, Brookville, and Clarion beds were tested. Six of the eight coals ranked low in the high-volatile A bituminous group and contained too much sulfur (2.5 to 5.1 percent) to qualify chemically for metallurgical use. Although the shatter indexes were satisfactorily high, the tumbler indexes of their cokes were low. By present standards these coals are unsuitable for carbonization as major constituents of metallurgical blends. The Brookville and one of the Upper Freeport coals ranked higher and contained less sulfur (1.6 and 1.7 percent) than the other Butler County coals. However, only the Upper Freeport coal yielded coke comparable with that of acceptable metallurgical coals of similar fixed-carbon content.

Indiana County. - Lower Kittanning coal, which is medium-volatile bituminous in rank, yielded metallurgical coke with satisfactory physical properties but was exceptionally high in sulfur (4.4 percent) and moderately high in ash. This coal expanded 4.5 percent in the sole-heated oven. The high sulfur content, with the expanding characteristics of this coal, would limit its use to a minor constituent in coking blends.

Greene County. - Pittsburgh and Sewickley coals from Greene County were relatively high in sulfur (2.6 and 2.3 percent) for metallurgical use. A previously published study of the preparation properties of Pittsburgh-bed coal in this county[74] indicates that coal from this bed cannot be considered as metallurgical fuel where the sulfur in the raw coal exceeds 2.27 percent. Both coals yielded coke somewhat weaker than other Appalachian coals of similar rank.

Mercer County. - High-volatile A Brookville-bed coal, the only coal tested from this county, was moderately high in sulfur and yielded weak coke; these properties would limit its use as a metallurgical coal.

Somerset County. - Six samples of low-volatile coals from the Upper and Lower Freeport and Upper and Lower Kittanning beds coked as strongly as Pocahontas No. 3 (a widely accepted low-volatile blending coal) from McDowell County, W. Va., in binary blends with high-volatile A Pittsburgh-bed coal from Washington County, Pa. The 1-1/2-inch shatter and 1-inch tumbler indexes increased progressively and significantly as the percentage of each low-volatile coal in the blend was raised from zero to 10, 20, and 40 percent; whereas, the 1/4-inch tumbler index increased only slightly. As differences in coke strength from the equivalent blends, including those containing Pocahontas No. 3, were negligible, it may be concluded that the Somerset County low-volatile coals are satisfactory low-volatile metallurgical blending coals. The sulfur content for these Somerset County coals ranged from 0.6 to 2.1 percent.

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[74] Fraser, Thomas, Crentz, W. L., and Bailey, A. L., High-Sulfur Pittsburgh Coal; Upgrading in Southwestern Pennsylvania and Northern West Virginia: Bureau of Mines Bull. 483, 1950, 70 pp.

Kentucky Coals

Harlan County. - Thirteen coals, representing 9 beds, contained 56.8 to 61.1 percent fixed carbon on the dry, mineral-matter-free basis and gave relatively low coke yields. These yields were about 2.2 percent less than the average (69.1) for 20 high-volatile A Appalachian region coking coals that have been used commercially for the production of metallurgical coke. With few exceptions their yields of gas, tar, light oil, and ammonium sulfate were higher than average. Harlan, Elkhorn No. 3, and "D" bed coals were low in ash and sulfur and yielded coke with satisfactory coke strength indexes for their fixed-carbon content. These coals could be used for producing metallurgical coke if properly blended with higher rank coal. Flag, Fire Clay, Amburgy, and the Harlan (lower split) bed coals yielded cokes with low tumbler stability and, in general, could not replace the better-coking Kentucky coals in metallurgical blends without some loss in coke strength. Haddix and Elkhorn No. 2 coals were high in sulfur and yielded weak coke, which would limit their use as metallurgical coals. However, Elkhorn No. 2 coal is now used commercially for metallurgical purposes, and another sample has been obtained from a low-sulfur area in this county for a further investigation of the coke-making ability of this bed.

Letcher County. - Although 8 coals from 7 beds in this county have been tested previously, only Leatherwood-bed coal was tested in this reporting period. Even though this coal yielded relatively weak coke when carbonized singly, it could probably be used for metallurgical purposes by proper blending with higher rank coal. Previous investigations have shown that Leatherwood coal, from other mines, responds well to blending with low-volatile coal to yield a satisfactory metallurgical coke.

Pike County. - Alma coal, which was low in sulfur and ash, contained 61.3 percent dry, mineral-matter-free fixed carbon and yielded 68.3 percent coke. The physical properties of the coke were similar to those of the average coke from high-volatile coking coals.

Four samples of Pond Creek coal from this county were tested in an investigation of the effect of commercial storage on carbonizing properties.[75] Fresh coal sampled at the mines, 2 samples of stored coal from the interior, and 1 sample from the exterior of a 50,000-ton stockpile, which had been laid down 18 months previously, had similar coking properties in BM-AGA tests. The conclusion that the coking properties of Pond Creek coal were not affected significantly by 18 months storage was substantiated by industrial-scale carbonization tests by the company storing the coal.

Perry County. - Four coals from the Hindman, Haddix No. 5, and Hazard No. 4 beds ranked low in the high-volatile A group, since they contained 57.3 to 59.5 percent dry, mineral-matter-free fixed carbon. The 1-1/2-inch shatter and 1-inch tumbler indexes of cokes from the Hindman and both Haddix coals were as high as those of coals containing more than 60 percent fixed carbon. Hazard No. 4 coke

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[75] Smith, Frank W., Reynolds, D. A., and Brewer, Ralph E., Effect of Storage on the Coking Properties of Pond Creek Coal From Pike County, Ky.: Proc. Am. Gas. Assoc., 1953, pp. 835-851.

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was weakest but was within the range for coals that have been used for metallurgical purposes. Hindman coal contained 2.8 percent sulfur and would therefore be limited for use as metallurgical fuel unless the sulfur content could be reduced by cleaning.

West Virginia Coals

Mingo County. - Seven coals from 5 beds contained 59.0 to 64.9 percent dry, mineral-matter-free fixed carbon and yielded 65.8 to 70.1 percent coke at 900° C. These values are within the ranges permissive for metallurgical coking coals. Six of the coals, representing the Coalburg, Buffalo Creek, No. 2 Gas, Alma, and Cedar Grove beds, coked strongly enough and were of suitable chemical composition to qualify for metallurgical use if properly blended with higher rank coal. An additional sample of Cedar Grove coal was high in ash and sulfur (10.1 and 2.0 percent, respectively) and yielded rather abradable coke; these properties would limit its use for metallurgical purposes.

Tennessee Coals

Putnam County. - Data on the carbonizing properties of coal from the Wilder (Bon Air No. 2) bed in Putnam County are given in a report[76] on reserves, preparation, and carbonizing properties of coal from this bed. Because of high sulfur and ash contents that cannot be sufficiently reduced by washing, this coal does not make coke that meets present chemical requirements for metallurgical coke. Yield of coke from Wilder bed coal was appreciably lower than the average for coals of comparable rank. Resistance to breakage of the coke was satisfactory according to present metallurgical standards, but the coke was low in both stability and hardness. Blending with higher rank coal would improve the indexes. Contraction characteristics of the coal would permit blending with the necessary amount of low-volatile coal to give satisfactory coke strength without forming a blend of dangerous expanding tendencies.

Claiborne County. - Coal Creek- and Jellico-bed coals contained 60.4 and 60.0 percent dry, mineral-matter-free fixed carbon and yielded 67.0 and 66.1 percent coke and 15.6 and 14.2 gallons of tar per ton, respectively. Although they were of about equal rank, Coal Creek coal yielded the stronger coke. However, both coked strongly enough to qualify as metallurgical coals.

Virginia Coals

Douglas-bed coal, which ranked as medium-volatile bituminous, contained only 3 percent ash and yielded excellent coke when carbonized singly. This coal would probably be blended with contracting coals if carbonized commercially because it expanded in laboratory tests in the sole-heated oven.

Colombia, South America, Coals

Three coals, No. 8, No. 0 (semibituminous[77] zone), and El Olivido from the Cauca Valley field, ranked as medium-volatile bituminous, and the fourth (No. 0 -

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[76] Williams, L., Lowe, R., Turnbull, L. A., Carman, E. P., Crentz, W. L., Reynolds, D. A., and Abernethy, R. F., Estimate of Known Recoverable Reserves and the Preparation and Carbonizing Properties of Coking Coal in Putnam County, Tenn.: Bureau of Mines Rept. of Investigations 5029, 1954, 21 pp.

[77] It may be noted that these local designations do not comply with the American standard classification of coals by rank.

anthracite[78] zone) was low in the low-volatile group. No. 0 (subbituminous[79] zone) and El Olivido contained moderate percentages of ash and sulfur; No. 8 and No. 0 (anthracite zone) were rather high (1.9 and 2.1 percent) in sulfur; and No. 8 was very high (25.6 percent) in ash. Lower Sunnyside coal from Utah was blended with each Colombian coal to determine the ability of the latter to strengthen the coke yielded by this high-volatile coal, which has coking properties similar to those of certain South American coals. Coke-strength tests were made by the Columbia Steel Co. method, which is used for testing weak cokes from western United States coals. The coke-making properties of the Colombian coals differ markedly when carbonized singly. No. 8 was noncoking; No. 0 (anthracite zone) yielded char too small and weak to test; No. 0 (semibituminous zone) yielded coke slightly weaker than Sunnyside coke; and El Olivido coked more strongly than Sunnyside. In tests as blends with 85 percent Lower Sunnyside coal, each Colombian coal improved the cokemaking property of Lower Sunnyside about as much as Pocahontas No. 3. The large differences in the coking properties of the Colombian coals when they are carbonized singly largely disappeared when they were tested as minor constituents (15 percent) of blends with Lower Sunnyside coal.

Philippine Island Coals

The coals tested were from the C bed of high-volatile A rank, the No. 2 bed of high-volatile C rank from Mindanao, and the Santa Filomena and Garcia beds of high-volatile B rank from Cebu. Carbonization tests were made on the single coals and on blends with C-bed coal. Properties of cokes from the single coals were determined by ASTM methods. Compared to 20 high-volatile A Appalachian region coking coals that have been used commercially for the production of metallurgical coke, C coal yielded fair coke, Santa Filomena and Garcia coals yielded weak coke; and the No. 2 coal yielded coke that was too poorly fused to test. Tests by the Columbia Steel Co. tumbler method of cokes from several blends showed that the 70 to 30 blend of C and Santa Filomena and the 80 to 20 blend of C and Garcia coals yielded coke comparable to that from an 85 to 15 blend of Sunnyside and Pocahontas coals, which has been carbonized commercially for metallurgical coke.

Mechanism and Kinetics of Coal Carbonization

To furnish fundamental data on the carbonization of coal and to develop new techniques for assessing the factors that affect coking, the Bureau of Mines has undertaken a program on the study of the mechanism and kinetics of coal carbonization. Several projects have been initiated for studying the fundamental rate processes controlling coking. One of these projects involves investigating relatively simple carbonaceous materials, such as specially prepared coal-tar pitches of high melting point and purity, under closely defined test conditions. The results obtained with the simpler systems will be integrated with results on blends of such pitches with other carbonaceous materials and with coal. Data already obtained are useful in evaluating the effect of fluidity on coking properties and furnish quantitative support of the observed effects of fluidity in the coking of coals. These data confirm the long-held theory that coke strength depends upon the fluid properties of coal only when the materials are deficient in fluid materials and that the coke strength is virtually independent of fluidity when enough material for wetting all of the surfaces of particles in the plastic zone is available.

Another project involves study of the effects of pretreatment of coals on their carbonizing behavior. The coking properties of coal are known to vary with thermal and chemical treatments the coal receives below the fusion temperature. However, the effects of such pretreatments have not been completely evaluated nor are enough data available to determine the physical and chemical changes that occur before the fusion of coal. The study of the effects of pretreatment of coals on their carbonizing behavior appears to offer a promising means of arriving at a better understanding of the mechanism of coking. The objective of this work will be to control the coking properties, both thermally and by the addition of oxygen to the coal structure. Not enough data have been obtained yet in this study for publication.

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[78] See footnote 77.
[79] See footnote 77.

Coal Expansion During Carbonization

Sole-Heated Oven Tests

The Bureau of Mines sole-heated oven is used to determine the expanding properties of coals and blends. Only coals with more than 65 percent dry, mineral-matter-free fixed carbon are tested because, in general, coals with less fixed-carbon content contract.

As reserves of some of the low-volatile blending coals are becoming depleted, the Bureau of Mines is endeavoring to evaluate the carbonizing properties of coals of similar rank from other beds to facilitate the selection of replacement coals. Low-volatile coals are not carbonized singly in modern ovens because of their expanding properties, but since they have the ability to increase both the strength and yield of coke obtainable from nonexpanding coals of high-volatile rank, they are used widely as the minor constituent in blends to produce metallurgical coke. The coke-strength indexes of the coke formed by these high-rank coals when coked alone are of little interest because previous investigations have shown that the physical properties of their coke are not closely related to those of coke made from their blends with large proportions of high-volatile coal. However, as the expanding property of a low-volatile coal often is imparted, at least in part, to its blends, coke-oven operators are particularly interested in the expanding properties of the coal to forecast its suitability for blending.

Six low-volatile coals from the Upper and Lower Freeport and Upper and Lower Kittanning beds in Somerset County, Pa., low-volatile Pocahontas No. 3, a well-known blending coal, from McDowell County, W. Va., a high-volatile A Pittsburgh coal from Washington County, Pa., and blends containing 10, 20, 40, and 70 percent of each low-volatile coal with the high-volatile coal were tested in the sole-heated oven. Four of the six low-volatile Somerset County coals expanded approximately the same as Pocahontas No. 3 (26.0 percent), and the other two expanded 1.8 and 2.4 times as much. The lower rank Pittsburgh coal contracted 13.1 percent. All results are reported as percentage expansion or contraction, at a bulk density of 55.0 pounds per cubic foot, 1 percent moisture, and 0.3 percent plus-4 mesh coal. The difference in expansion of the individual low-volatile coals appeared to have little influence on the expanding properties of blends containing 10 to 40 percent of low-volatile coal. When 70 percent of the low-volatile coal was used, the expansion of the blends depended more on the expanding properties of the low-volatile coal. The range of expansion for the 10-percent low-volatile blends was minus -4.9 to minus-2.1; 20 percent, minus-1.3 to plus-2.9; 40 percent, plus-6.4 to plus-9.1; and 70 percent, plus-15.7 to plus-23.3 percent. Considering only expansion behavior, these six low-volatile Somerset County coals could be substituted for Pocahontas No. 3 in metallurgical blends, with a negligible change in the blending proportions.

Bench-Scale-Expansion Tests

A laboratory expansion test in which 71 grams of coal is used compared with approximately 40 pounds (18 kg.) in the sole-heated oven is being studied. The test time for the small unit is about 1-1/2 hours compared with 7-1/2 hours for the larger unit. Both units are heated similarly from the sole (or base). The small tester includes a cylindrical steel retort 6 inches in diameter in the center of which is placed a light-gage metal can approximately 2-1/2 inches in diameter. Both the can and the annular space are charged with the coal to be tested to a thickness of 1 inch at a bulk density of about 55.0 pounds per cubic foot. An annular piece of steel rests on the coal outside of the can and applies a load of 2.2 pounds per square inch. An insulated weighted piston rests on the coal inside the can and applies a similar load. The linear movement of the piston is determined by a cathetometer, and expansion or contraction measurements of the coal during coking are determined thereby. The retort rests in a cast refractory block containing Nichrome heating coils. Three circuits with variable control are used to insure uniform heating of the coal charge within the can where the expansion measurements are made. A series of tests has been made on Pittsburgh-bed coal with this small-scale expansion tester to determine the reproducibility of test. Later, experiments will be made to correlate the small tester with the larger sole-heated oven.

Tests With Tuscaloosa Oven

An analysis of the results obtained in preliminary tests with the Tuscaloosa oven and a consideration of the conditions of operation prevailing in commercial and experimental coke ovens led to the development of a set of standardized operating and testing procedures for use with the Tuscaloosa oven.80/ Subsequent investigations using these procedures have yielded information on the effects of variations in bulk density on coking time.81/ The principal conclusion from this study was that the coking time is essentially proportional to the density of the coals charged, and that coal type and moisture content have relatively little influence except in so far as they affect charge density.

Initial phases of a long-range study of coal expansion have been completed at the Bureau of Mines Tuscaloosa, Ala., station. A report discussing selected aspects of this work proposed a fundamental relationship between the force exerted on an oven wall and the gas pressure measured at the charge center.82/ Another section of this report presented data indicating that the Tuscaloosa oven was suitable for use in investigating factors causing "stickers" or "hard pushing ovens" in commercial practice.

Substitution of Anthracite for Bituminous Coal and Coke for Metallurgical Use

Various applications of anthracite to metallurgical processes have been investigated during the year in a search for data leading to resumption of former usage

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80/ Gayle, J. B., and Gulledge, E. L., Carbonizing Procedures With New Experimental Coke Oven: Bureau of Mines Rept. of Investigations 5011, 1954, 12 pp.

81/ Gayle, J. B., and Gulledge, E. L., Effects of Variations in Bulk Density on Coking Time: Bureau of Mines Rept. of Investigations 5027, 1954, 9 pp.

82/ Gayle, J. B., Eddy, W. H., and Brooks, J. A., Studies of Coal Expansion.
1. Fundamental Relation Between Measured Gas and Wall Pressures.
2. Factors Influencing Pushing Pressures for Slot-Type Ovens: Pres. at Chemical Engineering and Manufactured Gas Production Conference, Operating Section, Am. Gas. Assoc., Pittsburgh, Pa.; Proc. AGA 36th Ann. Convention, 1954, pp. 628-634.

or the development of new markets. Several iron-smelting blast-furnace plants were visited where lump anthracite had been used in recent years in small proportions as furnace fuel in times of coke shortages. Anthracite up to 20 percent of the total fuel had been substituted in some smaller furnaces (18-foot hearths) and to a maximum of 10 percent in the larger furnaces. All reported some 5- to 10-percent reduction in furnace output, increased total fuel used per ton of iron, and substantial operating difficulties that appeared to result from the reduced permeability of the stock column. The reduced permeability was attributed to both the smaller volume of the much denser coal and disintegration of the coal lumps by the effects of shattering, abrasion, and thermal shock. Furthermore, the slower combustion of the small-size coal permitted it to reach and accumulate in the hearth below the tuyères. All plants resumed all-coke operation when adequate supplies became available.

Attempts to use anthracite as the main fuel in 10- and 12-foot-diameter furnaces producing spiegeleisen at a zinc plant in the anthracite region some years ago were reported unsuccessful because of conditions closely paralleling the iron-furnace experience.

Commercial blast-furnace design over the last 50 to 75 years has been entirely on the basis of the use of coke as fuel. However, recently there has been activity in the anthracite region to develop low-shaft metallurgical blast furnaces, with the use of anthracite as one goal. The Bureau is cooperating in these efforts.

It has been possible to use coke from weakly coking western coals in some far-western blast furnaces by careful preparation and sizing of the iron ore to promote stock-column permeability. To determine whether similar care would be likely to give equal results if anthracite were substituted for the western cokes, comparative studies were made of the physical properties of these cokes and anthracite. It was found that the western cokes not only had the advantages of low density but that their shatter and abrasion indexes were superior to those of anthracite.

The history of anthracite as fuel in metallurgical remelting cupolas paralleled experience in blast furnaces. One plant in which a cupola installed to give "hot" (molten) metal for charging open-hearth steel furnaces was operated a few years ago with 40 percent Egg-size anthracite and 60 percent low-grade coke as fuel on 3-day runs for several months. Capacity dropped slightly, lining erosion increased, and unconsumed dust collected in the hearth, but tapping temperature was maintained regularly; however, all-coke operation was resumed, in spite of the higher coke price, as soon as adequate coke supplies became available.

An effort was made to improve the abrasion-resisting characteristics of Egg-size anthracite by preliminary slow heating or calcining to 1,750° F. to relieve internal stresses. Abrasion stability was doubled (although still less than 50 percent of weak furnace coke), but resistance to shatter was lowered. In a test run in a commercial foundry cupola with this treated coal - after the initial charge with coke - fresh air rate and tapping temperature could not be maintained, even for a 4-hour pour. An investigation has been started to determine the possibilities of preparing briquets from fine-size anthracite that may have properties adapted to use in blast-furnace and cupola practice.

Anthracite was investigated as a source of additional carbon in open-hearth steel practice, particularly in cold-metal shops where hot pig iron is not available and a large part of the charge is low-carbon scrap. In the anthracite region this coal has the advantage of lower price and usually lower sulfur content than coke, but there are only some 5 or 6 such plants in the region that are not integrated with coke-producing facilities. The volatile content of the anthracite places it at a disadvantage, as some of the hydrogen present may remain in the steel and the remainder of the gases can cause foaming of the slag and other difficulties as the refining proceeds. An accepted practice is to charge half of the carbon additive as coke on the furnace bottom and the remainder as anthracite in increments with the scrap, so that the coal is consumed during the meltdown of the cold charge and its volatile matter escapes before the full slag is formed. Preliminary calcination of Lump anthracite reduced the volatile content below that in coke which, from a technical standpoint, should make anthracite suitable for supplying the whole carbon addition.

The practice of admixing small percentages of anthracite fines with coking coals, which was undertaken on a commercial scale as early as 1941 by at least 1 coke-oven plant, has grown to the extent that, except for 1949 and 1950, over 200,000 tons of anthracite fines has been charged to coke ovens annually during the past decade. Significantly, with the drop in production rate in the iron and steel industry from 1953 to 1954, the percentage decrease in tonnage of anthracite fines charged to coke ovens during the same period is smaller than the percentage decrease in the total tonnage of bituminous coal charged at furnace and merchant plants and is much less than the percentage decrease in tonnage of bituminous coal charged at merchant coke plants for this period. This appears to reflect a valuable element of stability in this market for anthracite fines. In 1954 a new fine-coal-preparation plant was placed in operation in the Eastern Middle field of the Pennsylvania anthracite region; it was designed with the anthrafines-blending market, along with others, in view and equipped to supply a premium-quality, clean, well-sized product for blending.

The practice of blending small percentages of selected anthrafines with suitable coking coals permits the use of higher oven flue temperatures, where these are not already at the limit, and thereby permits increasing oven throughputs. Other advantages are improved size uniformity, with no material change in or even some improvement in coke strength, and somewhat greater flexibility of coal selection at coke-oven plants, since anthrafines can be used to reduce the expansion of expanding coking coals. This and other factors involved in the use of anthrafines as blends to produce metallurgical coke have been studied by the Bureau of Mines, and results of the investigation are being prepared for publication.

Low-Temperature Carbonization of Lignite for Thermal Electric Power Production

Estimated fuel balances for an integrated 240,000 kw. thermal-power plant using the Bureau-developed entrained-bed drying and carbonizing process indicate that 6,920 tons of 7,000-B.t.u.-per-pound Texas lignite would be required per day, producing 108,000 gallons of tar and light-oil per day, according to a report[83] covering initial operations of the Rockdale, Tex., plant built by the Texas Power & Light Co. to supply power for an aluminum-reduction plant of the Aluminum Co. of America. If North Dakota lignite having a heating value of 6,800 B.t.u. per pound were used, 5,920 tons would be required per day, with a daily production of 62,800 gallons of tar and light oil. On the other hand, if a Wyoming subbituminous coal were used with a heating value of 9,900 B.t.u. per pound, 4,390 tons would be required per day and produce 95,600 gallons of tar plus light oil.

83/ Parry, V. F., and Landers, W. S., Low-Temperature Carbonization of Lignite for a 240,000-kw. Steam-Electric Power Plant: Pres. at World Power Conference, Sec. Meeting, Rio de Janeiro, Brazil, July 25 - Aug. 8, 1954.

At the Rockdale plant the full complement of nine entrained-bed driers was completed and tested, and they were in operation as required to supply dried lignite directly to the pulverized-fuel burners in the boiler plant. The prototype 750-ton-per-day carbonizer was operated to produce chars and tar and chemical products for tests of their characteristics and utilization possibilities. Bureau engineers cooperated in observing operating tests and in studies of low-temperature tars from the carbonizer.

GASIFICATION OF COAL AND LIGNITE

Conversion of Coal to High-B.t.u. Gas

Because natural gas has certain advantages over other types of fuel, the demands for natural gas have greatly increased; as a result, its cost has increased. In view of this and the fact that natural gas, like any natural resource, is an exhaustible commodity, the Bureau of Mines investigated the possibility of producing high-B.t.u. gas from coal as an alternative source for pipeline fuel. In the first phase of the project methanation of $CO + H_2$ produced by gasifying coal was studied and a method was developed for catalytically converting $CO + H_2$ to methane. A report on this study will be published later.

Anthracite for Making Producer Gas

An investigation of the manufacture of anthracite producer gas for industrial process heating originally was undertaken as a means of supplying the anthracite industry, as well as manufacturers and prospective users of the equipment, with information on performance and operating characteristics of commercial anthracite gas-producer equipment. Field work at one shale-brick plant has been completed, and an exterior view of one side of a rectangular, downdraft, periodic kiln fired with hot anthracite producer gas is shown in figure 21. Because of contemplated changes, maintenance on these kilns has been sufficient only for keeping them operable; consequently, the kilns are not as gastight as when more rigorously maintained. As a result, the fuel consumption has not changed appreciably in going from coal hand-firing to gas firing. Nevertheless, gasifying has reduced overall manufacturing cost of brick, because increased uniformity of heating with gas firing has improved product quality and yields, as well as permitting faster heating. Anthracite producer-gas firing also has decreased the effects of seasonal changes in weather on the heating of the exposed batch kilns. During a 2-week observation period, 300 tons of Rice and Buckwheat anthracite was gasified at this plant in a twin producer installation to yield about 42 million cubic feet of producer gas at 60° F. The average hot-gas efficiency of the producers was 90 to 93 percent for gas leaving the producers at an average temperature of 530° F. Publication of a complete report of the results of this study is planned.

Two series of tests of the gasification of pulverized anthracite with oxygen and steam were made in equipment at the Bureau of Mines Appalachian Experiment Station, Morgantown, W. Va. One series consisted of runs using a 36-percent-ash culm in the pressure gasifier at 300 p.s.i.g. The other series of tests was made with a 10-percent-ash coal in the atmospheric pressure gasifier. Further tests were found necessary for obtaining adequate data to compare these results with those obtained when using bituminous coals, and to develop modifications in the design of the reaction chambers to eliminate the buildup of slag when using anthracite in both types of gasifiers.

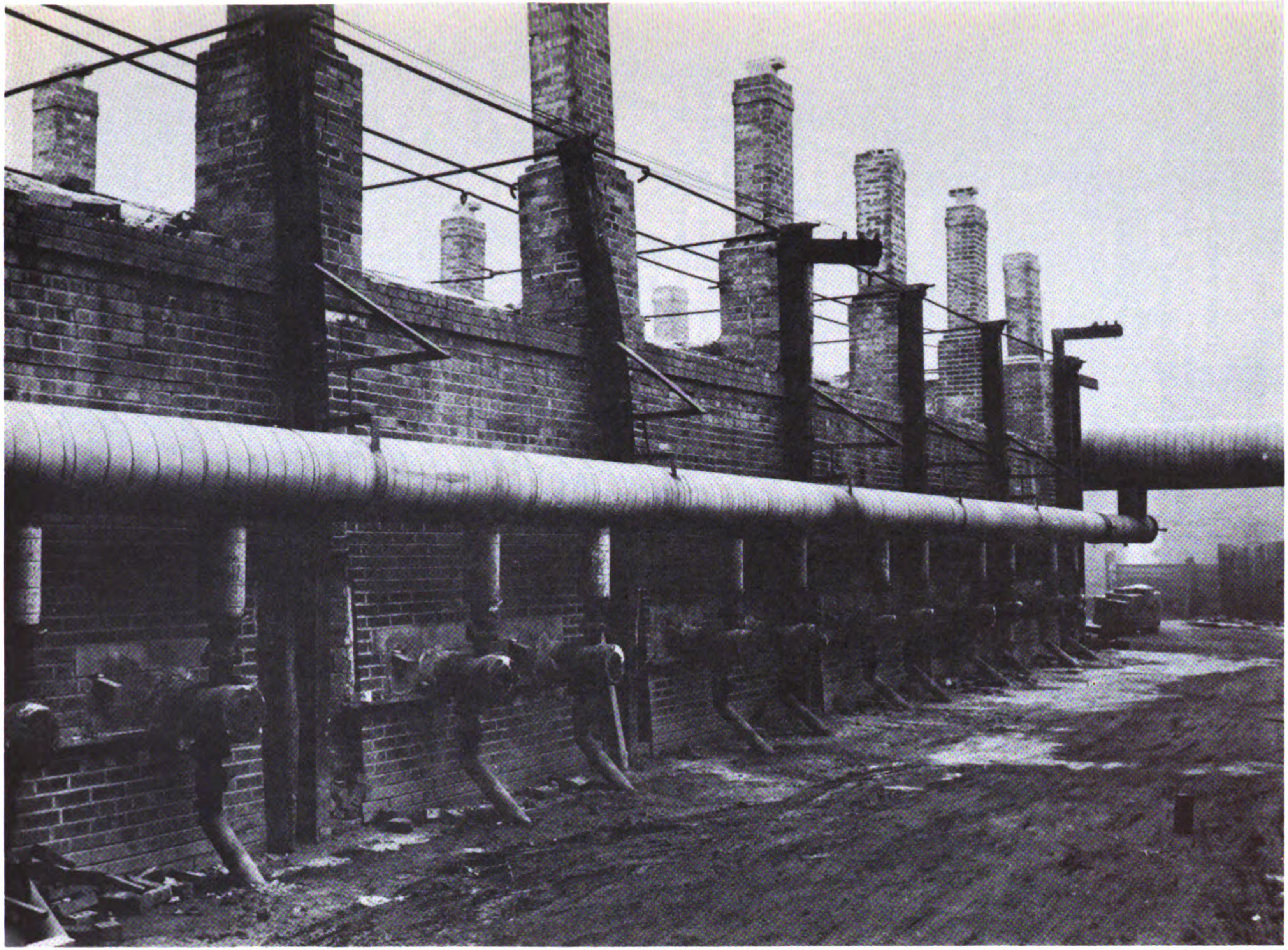

Figure 21. - Brick kiln fired with anthracite producer gas.

Underground Gasification

Processes for underground gasification of coal in place require drill holes or shafts from the surface to the coal bed and a link between these entries to permit flow of gases through the coal. In early experiments, passages in the coal bed were made by actual mining, an expensive and laborious procedure. Later, various schemes were proposed for underground linking of shafts driven into coal beds. Tests using the electrolinking procedure showed that it was possible to open passages in the bed by this method.[84/] Hydraulic fracturing, now used to increase the productivity of oil wells, is another method proposed for accomplishing the same purpose. The process consists essentially of forcing a sand-in-liquid suspension into the ground under high pressure and removing the liquid, thus leaving the sand grains underground to keep the network of pores and fissures developed by the high-pressure fracturing from collapsing. By applying this process, the permeability of the strata is thus increased greatly, as was the flow of many oil wells in which it was used. The first such experiment in coal was made at Gorgas during the year, and air-distribution tests indicated that a large volume of coal was affected by the hydraulic fracturing. Gasification tests are planned early in 1955.

RESEARCH ON PRODUCTION AND PURIFICATION OF SYNTHESIS GAS

Gasification

Most of the Bureau of Mines work on gasification of coal with steam and oxygen (or air) to produce gases suitable for use in synthetic-fuels processes has been carried out at the Bureau facilities at Morgantown, W. Va., now moved into the Appalachian Experiment Station there.

The gasification process, primary products of which are hydrogen and carbon monoxide, may be carried out at various pressures. Development of designs and operating procedures applicable at atmospheric pressure was concluded by the Bureau when a large-scale industrial unit was built that incorporates many features that were developed by the Bureau in cooperation with an engineering firm. Work on pressure gasification is continuing in pilot-scale equipment in the new laboratory (see fig. 22).

American developments in the field of gasification were reviewed at an international conference in Belgium.[85/] Studies by the Bureau of Mines at Morgantown are described in a Bureau publication,[86/] which contains details of the plant, description of the procedures, discussion of results, and a cost evaluation of the process. Operating conditions were flexible enough to allow variation of the H_2-CO ratio from 0.7 to 1.15. In the course of this work, a device was designed for visual observation of dense-phase suspensions.[87/]

[84/] Fies, M. H., and Elder, J. L., Fuels Technology - Underground Gasification of Coal at Gorgas, Ala.: Mech. Eng., vol. 76, No. 2 February 1954, pp. 189-190.

[85/] Newman, L. L., Developments in the Oxygen Gasification of Solid Fuels on the American Continent: Internat. Conf. on Complete Gasification of Mined Coal, Liege (Belgium), May 3-5, 1954, Sec. A, Paper A1, 17 pp. (English text): 19 pp. (French text); 19 pp. (German text).

[86/] Strimbeck, G. R., Cordiner, J. B., Jr., Baker, N. L., Holden, J. H., Plants, K. D., and Schmidt, L. D., Gasification of Pulverized Coal With Steam and Oxygen at Atmospheric Pressure: Bureau of Mines Rept. of Investigations 5030, 1954, 37 pp.

[87/] Bonar, F., and Pears, C. D., Method and Device for Visual Observation of Dense-Phase Suspensions: U. S. Patent 2,650,562, Sept. 1, 1953.

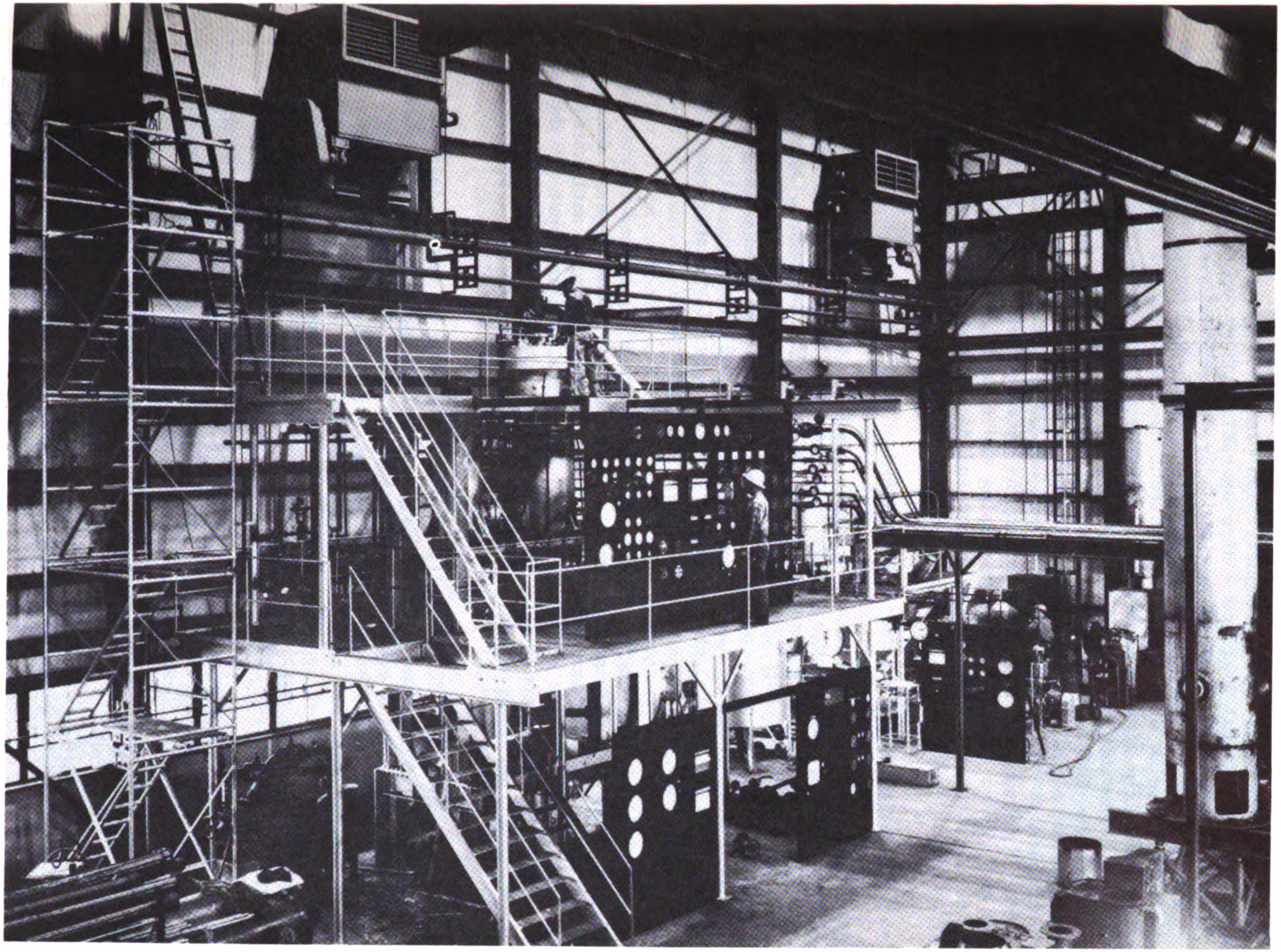

Figure 22. - High-pressure pilot-scale coal-gasification apparatus in new Appalachian Experiment Station, Morgantown, W. Va.

At the Bureau of Mines former demonstration plant for synthetic liquid fuels at Louisiana, Mo., a commercial gasifier - also operating at atmospheric pressure with steam and oxygen - was operated for about 400 hours before the plant was closed in 1953.[88] Of the operating variables studied, the oxygen-coal ratio had the greatest effect on the performance of the unit; the extent of conversion of coal to gas increased almost linearly with increases in that ratio. Apparently, the most favorable conditions economically existed when 9 to 10 cubic feet of oxygen was used for each pound of coal. Under those conditions, 80 to 85 percent of the carbon in the coal was converted to gas. On the basis of these and other experiments, engineering calculations were made to evaluate the effects of oxygen-coal ratio and time on the extent of conversion of carbon and on the yields, temperatures, and heat contents of the gases. In a report summarizing the results,[89] the graphs shown permit rapid calculation of the cost elements and facilitate choice of the most economical operating conditions.

Purification

The reaction of coal with steam and oxygen produces a gas containing dust and undesirable diluents, of which carbon dioxide is the most abundant. In commercial practice, this gas is generally removed by absorption in ethanolamine. When the synthesis gas is under at least 200 p.s.i.g. pressure, absorption in a hot, concentrated solution of potassium carbonate may prove to be more economical; under these conditions, less steam is needed for regeneration of scrubbing solution, loss of solution is negligible, the amount of cooling water is greatly reduced, and heat exchangers and cooling equipment can be eliminated.[90]

The demonstration plant of the Bureau of Mines, which was closed before the new process became available, used diethanolamine as the scrubbing agent, followed by iron oxide for removal of remaining hydrogen sulfide and then by activated carbon to take out organic sulfur compounds. The usual rate of throughput per day was 2 million cubic feet of gas containing 16 to 20 percent carbon dioxide and about 100 grains of sulfur per 100 cubic feet. The purified gas contained 2 to 5 percent carbon dioxide and less than 0.01 grain of sulfur.[91]

A study was made of the adaptability of a shaft filter to remove dust from gas produced by gasification of coal. This filter was originally developed to collect carbon black (made by partial combustion of acetylene with oxygen). The shaft is filled with granular coke on which the fine particles are deposited as the gas stream passes through from the bottom. When resistance to flow reaches a certain value, because of clogging of pores by dust, some coke is dropped through the grate at the bottom of the shaft, dust is washed off the coke, and clean coke is returned through the top of the shaft. The design of the filter was modified to increase its efficiency. Although the flow of gas need not be interrupted for cleaning and cycling of coke, the necessary periodic reactivation makes filtering semicontinuous. Operating cycles ranged from 15 minutes to 6 hours, depending on the amount of dust in the gas. From 96.5 to 99.5 percent of dust was removed from synthesis gas, depending primarily on the fineness of the particles.[92/][93/]

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[88] Dressler, R. G., Batchelder, H. R., Tenney, R. F. Wenzell, L. P., Jr., Hirst, L. L., Operation of a Powdered-Coal Gasifier at Louisiana, Mo.: Bureau of Mines Rept. of Investigations 5038, 1954, 35 pp.

[89] Batchelder, H. R., and Busche, R. M., Kinetics of Coal Gasification; Design of Atmospheric Pressure Gasifiers: Ind. Eng. Chem., vol. 46, No. 12, December 1954, pp. 2501-2508.

[90] Benson, H. E., Field, J. H., and Jimeson, R. M., CO_2 Absorption Employing Hot Potassium Carbonate Solution: Chem. Eng. Prog., vol. 50, No. 7, July 1954, pp. 356-364.

[91] Wenzell, L. P., Jr., Dressler, R. G., and Batchelder, H. R., Plant Purification of Synthesis Gas: Ind. Eng. Chem., vol. 46, No. 5, May 1954, pp. 858-862.

Methods and devices for sampling gas streams under various conditions, and for analysis and characterization of solid and liquid impurities have been either newly developed or adapted to meet the needs of the Bureau of Mines gasification program.[94/] One of these methods concerns determination of the amount of carbonyl sulfide in synthesis gas. Modification of the methylene blue method permits determination of this sulfide without interference from carbon disulfide, ethyl mercaptan, or thiophene.[95/]

Methanation

Utilization of mixtures of hydrogen and carbon monoxide (synthesis gas) is not restricted to production of synthetic liquid fuels; these gas mixtures also provide the raw material for the manufacture of such diverse chemicals as fertilizer, alcohols, and waxes. Furthermore, this synthesis gas may serve to make methane gas, which would be suitable for domestic as well as commercial consumption. The methanation process therefore would make it possible to use coal gasification in areas and at times when insufficient natural gas was available. Normally, synthesis gas must be purified before conversion to methane, because the catalyst that effects the reaction is easily poisoned by sulfur. Tests made with gas containing known amounts of sulfur as carbonyl sulfide showed that the activity of the catalyst and the heating value of the resultant gas remained relatively constant until 0.58 gram of sulfur had been deposited per 100 grams of nickel in the catalyst. Thereupon the activity dropped quite fast, and no suitable method has been found as yet for restoring the catalyst to full activity by removing accumulated sulfur.[96/]

SYNTHETIC LIQUID FUELS BY GAS SYNTHESIS

Synthesis With Iron Catalysts

In gas synthesis, also known as the Fischer-Tropsch process, a mixture of gases consisting essentially of hydrogen and carbon monoxide is passed over a catalyst to make a predominantly gaseous, liquid, or solid product, depending upon the conditions under which the reaction takes place. The greatest engineering problem of the process is removal of heat produced during synthesis at a rate

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[92/] Egleson, G. C., Simons, H. P., Kane, L. J., and Sands, A. E., The Moving-Bed Coke Filter: A Practical Method for Removing Dust from Gas Streams. Bureau of Mines Rept. of Investigations 5033, 1954, 8 pp.

[93/] Egleson, G. C., Simons, H. P., Kane, L. J., and Sands, A. E., Moving Coke-Bed Gas Filter for Dust Removal: Ind. Eng. Chem., vol. 46, No. 6, June 1954, pp. 1157-1162.

[94/] Kane, L. J., Wainwright, H. W., Shale, C. C., and Sands, A. E., Determination of Solid and Liquid Impurities in Synthesis Gas: Bureau of Mines Rept. of Investigations 5045, 1954, 23 pp.

[95/] Pursglove, L. A., and Wainwright, H. W., Colorimetric Determination of Carbonyl Sulfide in Synthesis Gas: Anal. Chem., vol. 26, No. 11, November 1954, pp. 1835-1839.

[96/] Wainwright, H. W., Egleson, G. C., and Brock, C. M., Laboratory-Scale Investigation of Catalytic Conversion of Synthesis Gas to Methane: Bureau of Mines Rept. of Investigations 5046, 1954, 10 pp.

rapid enough to prevent damage to the catalyst. This may be done in various ways, among them the use of cooling oil which completely floods the catalyst. Excellent temperature control was achieved in pilot-plant studies of this mode of operation with a reduced fused iron catalyst. The catalyst particles were kept in motion by upward flow of oil to prevent cementation and plugging of the reactor.

To obtain more rugged catalysts, laboratory tests were made that eventually led to pilot-plant experiments with massive iron in the form of steel shot and lathe turnings. These catalysts are superficially oxidized with steam, impregnated with alkali, and then reduced with hydrogen. Such treatment provides a comparatively large, roughened area on the surface of each particle and incorporates the alkali that appears to be needed for the production of liquid hydrocarbons. Lathe turnings proved particularly useful because they pack with a high fraction of void spaces, offering small resistance to flow of gas and oil and permitting the use of a fixed rather than moving bed of catalyst. They were the longest lived catalyst thus far used by the Bureau and permitted the highest operating temperatures, which resulted in greater yields of gasoline from the Fischer-Tropsch process than had been obtained previously at the Bruceton, Pa., laboratories.97/

In another modification of the gas synthesis process, fine iron catalyst was slurried with oil and gas was passed through the slurry. The catalyst was treated with ammonia before synthesis so that virtually all of the iron was converted to iron nitride. Earlier laboratory work at Bruceton had shown this pretreatment to result in an active catalyst that is resistant to oxidation and that yields a product rich in oxygen-containing organic compounds. The objective of the pilot-plant study was to obtain more detailed information on the characteristics of the products and on the potential value of the process for making intermediates used by the plastics and detergent industries. Under favorable conditions, up to 80 percent of the products, excluding water, were alcohols. Ethyl alcohol predominated, but significant quantities of methanol and higher alcohols were found.98/

Physico-chemical and engineering developments in the Fischer-Tropsch process were reviewed,99/ and the first part of a bibliography of the Fischer-Tropsch and related processes was published.1/

Oxo Reaction

The original oxo reaction consists of addition of a formyl group, CHO, and a hydrogen atom to an unsaturated hydrocarbon (olefin). The process, in which synthesis gas participates in the presence of a metal catalyst, has been extended

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97/ Benson, H. E., Field, J. H., Bienstock, D., and Storch, H. H., Oil Circulation Process for Fischer-Tropsch Synthesis: Ind. Eng. Chem., vol. 46, No. 11, November 1954, pp. 2278-2285.

98/ Schlesinger, M. D., Benson, H. E., Murphy, E. M., and Storch, H. H., Chemicals From the Fischer-Tropsch Synthesis: Ind. Eng. Chem., vol. 46, No. 6, June 1954, pp. 1322-1326.

99/ Storch, H. H., The Fischer-Tropsch Process; chap. in Chemistry of Petroleum Hydrocarbons by B. T. Brooks and others: Reinhold Publishing Corp., New York, 1954, pp. 631-646.

1/ Anderson, H. C., Wiley, J. L., and Newell, A., Bibliography of the Fischer-Tropsch Synthesis and Related Processes (In Two Parts). I. Review and Compilation of the Literature on the Production of Synthetic Liquid Fuels and Chemicals by the Hydrogenation of Carbon Monoxide: Bureau of Mines Bull. 544, 1954, 532 pp.

over a much wider range of compounds and to different types of reaction. For example, aromatic alcohols have been shown to be reducible to the corresponding hydrocarbons by hydrogen in the presence of carbon monoxide and an oxo-type catalyst.[2]

In an extension of the study of oxo catalysts, a new type of organometallic compound was prepared from dicobalt octacarbonyl and acetylene derivatives.[3] Two of the eight carbonyl groups in dicobalt octacarbonyl form bridges between the two cobalt atoms. These two groups can be replaced by acetylene or some of its derivatives. The new complexes are thought to be related to postulated surface complexes formed on metal catalysts during the Fischer-Tropsch reaction.

SYNTHETIC LIQUID FUELS BY COAL HYDROGENATION

Laboratory Research

The chief chemical difference between petroleum and coal is that the coal contains less hydrogen. Therefore, to produce oils with properties similar to those of petroleum oils, hydrogen is reacted with coal at elevated temperatures and pressures in the presence of suitable catalysts. Despite the work done in many countries on this process, much remains to be learned about the fundamental nature of the reactions taking place during coal hydrogenation. For this reason, increased emphasis in the Bureau of Mines laboratories is being put on a study of chemical reactions of pure compounds (coal "models") and of coal itself with hydrogen. Such tools as theoretical chemistry,[4] analytical, organic, magneto, and radio-chemistry (radioactive tracers), microbiology, X-ray diffraction, and spectrometry (mass, ultraviolet, and infrared) are being used to follow physical and chemical changes that occur in reactions of organic materials.

In conventional coal hydrogenation, coal is pasted with oil before being introduced into the reactor. Some of the constituents of the oil dissolve some of the constituents of coal and thus probably play a role in hydrogenation. As part of the work on solvation of coal, the reduction of simple olefins with sodium in liquid ammonia was studied. The opinion that isolated carbon-carbon double bonds are inert in metal-liquid ammonia systems was invalidated.[5]

Characterization of products from coal hydrogenation is difficult not only because so many different types of compounds are present but also because compounds in the same group are hard to separate from each other. A relatively new device, the molecular still, has been used for distilling fluoranthene-chrysene mixtures dissolved in polyglycols. Fluoranthene was recovered in good yield and relatively free of the closely related polynuclear chrysene. Fairly pure chrysene was obtained only after repeated distillation.[6]

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[2] Wender, I., and Orchin, M., Reduction of Aromatic Carbinols: U. S. Patent 2,682,562, June 29, 1954.

[3] Sternberg, H., Greenfield, H., Friedel, R. A. Wotiz, J., Markby, R., and Wender, I., A New Type of Metallo-Organic Complex Derived From Dicobalt Octacarbonyl and Acetylenes: Jour. Am. Chem. Soc., vol. 76, No. 5, Mar. 5, 1954, p. 1457-1458.

[4] Manes, M., Hofer, L. J. E., and Weller, S., Reply to Christiansen's letter Chemical Kinetics and Equilibrium: Jour. Chem. Phys., vol. 22, No. 9, September 1954, pp. 1612-1613.

[5] Greenfield, H., Friedel, R. A., and Orchin, M., The Reduction of Simple Olefins With Sodium and Methanol in Liquid Ammonia: Jour. Am. Chem. Soc., vol. 76, No. 5, Mar. 5, 1954, pp. 1258-1259.

[6] Cantoni, A., Feldman, J., and Orchin, M., The Separation of Fluoranthene and Chrysene by Molecular Distillation: Anal. Chem., vol. 26, No. 8, August 1954, pp. 1374-1377.

Pilot-Plant Development

As now studied in the Bureau of Mines Bruceton, Pa., laboratories, the single-step process for direct conversion of coal to gasoline differs from the conventional process in that the liquid- and vapor-phase stages are combined in 1 unit that operates at about 500° C. with a large quantity of catalyst. Continuous, bench-scale equipment has been used for exploratory work, and a pilot plant was built for developing operating techniques and reactor design.

A reasonable hypothesis of events occurring in the small equipment is as follows: Slug flow of coal-oil slurry probably occurs at the inlet of the reactor and vehicle oil is vaporized almost immediately. The vapors attain a velocity comparable with that of hydrogen and are hydrogenated to gasoline and higher-boiling hydrocarbons. During flashing, coal is converted in a matter of seconds to primary products such as asphaltenes and heavy oils. These fractions are pushed through the tube and form a rather thin film on the wall. Here, they are hydrogenated into lighter fractions and are swept out as vapor. A steady-state film should thus be established, the thickness of which should be a function of the rate of paste input. Hence, in this unit virtually no control of contact time of product oil with hydrogen can be achieved.

The major difficulty in operating the pilot plant has been in dissipating the heat of reaction. Unsuccessful attempts were made to solve the problem by establishing a longitudinal temperature gradient in the reactor, by lowering the concentration of catalyst, and by using a higher molecular weight pasting oil. Internal cooling with hydrogen resulted in moderately successful operation at 480° to 510° C. However, the temperature was not uniform throughout the reactor. A new reaction system is now being designed.

SYNTHETIC LIQUID FUELS PUBLICATIONS

The problems involved in developing processes for converting coal to gas, liquid fuels, and bulk organic chemicals were reviewed in two foreign publications,7/ and the Bureau of Mines work in this field was described in domestic trade journals.8/9/10/

7/ Storch, H. H., Research and Development on the Conversion of Coal to Gas, Liquid Fuels, and Bulk Organic Chemicals: South African Min. and Eng. Jour., vol. 64, pt. 2, Jan. 30, 1954, pp. 791, 793, 795, and 797; also Trans. Canad. Inst. Min. Met., vol. 56, 1953, pp. 386-390.

8/ Storch, H. H., Federal Research on Synthetic Fuels by the Bureau of Mines: The Oil Forum, vol. 8, No. 1, January 1954, pp. 30-32.

9/ McKay, D., McKay Cites U. S. Synthetic Fuels Program. Jour. Commerce and Commercial (New York), vol. 242, No. 18, p. 267; Nov. 8, 1954, pp. 13, 16, and 17.

10/ Forbes, J. J., Developments in Synthetic Liquid Fuels: Mines Mag., vol. 44, No. 11, November 1954, pp. 111-114 and 158.

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